Vol. 3 JUNE, 1920 No. 6

Journal

—OF THE—

American Ceramic Society

A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries

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Published Monthly by the

AMERICAN CERAMIC SOCIETY

Publication Office: 211 Church St., Easton, Pa.

SIX DOLLARS PER YEAR (Foreign Postage Additional) *SINGLE NUMBERS, SIXTY CENTS*

Entered as second-class matter, July 15, 1918, at the postoffice at Easton, Pa., under the Act of March 3, 1879.

Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized August 16, 1918.

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JOURNAL
OF THE
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Vol. 3 **June, 1920** **No. 6**

EDITORIALS

PURE *versus* APPLIED SCIENCE

There has been some discussion here and there as to the relative value of the contributions toward the advancement of ceramic knowledge made by scientists and technical ceramists. It has been claimed that the former class has contributed more substantially than the latter and that, hence, scientific research, *per se*, is the predominating factor. Furthermore, it has become in vogue among chemists to accuse the ceramic industries of being backward and unscientific.

Such discussions are in the nature of the case of doubtful value since they raise the old question of pure *versus* applied science. It is obvious that we must first have pure science in order to apply it. The question, therefore, reduces itself to the issue whether the technical work of the ceramic industries would be better directed by men trained solely in the sciences than by those combining a certain amount of scientific training with specialized instruction in ceramic technology. This evidently neglects the very important factor that those having a leaning towards general scientific research usually have no desire to engage in industrial work.

Since the subject of ceramics, in the nature of the case, stands for the application of the several sciences to industry, the criterion of success must be the tangible results represented by decreased cost of production, fuel economy, the evolution of new products and processes, the control of manufacturing operations, etc. Considered from this standpoint, the investigators of pure science

can not make a convincing or even creditable showing. Magnificent porcelain has been made for many decades without a knowledge of its micro-structure; excellent silica brick have been produced for many years without a knowledge of the silica inversions; glasses of many varieties have been manufactured successfully for a long time; portland cement of good quality has been made for almost a century by methods based only on simple chemical procedure; the continuous and tunnel kilns owe nothing to the scientific investigator. These and many other accomplishments have been brought about through empirical procedure and experimentation, governed by the same inexorable laws of cause and effect as strictly scientific investigation. Far be it from us to decry scientific work or to deny the necessity of lending it our full support; but the two fields, pure and applied science, are distinct and separate. To consider, for instance, the subject of ceramics to be a branch of physical chemistry is erroneous, to say the least. The physical chemist deals with general problems and methods pertaining to pure science, irrespective of any industrial application. It is the function of the ceramist to acquaint himself with the principles of those sciences having a direct bearing upon his field *and in addition* to master the treatment of materials, furnaces and kilns, which constitute the basic part of manufacture. Furthermore, he must be familiar with the history, development and economic status of his industries. A physical chemist, no matter how accomplished he may be in his science, has not mastered the subject of ceramics unless he possesses all of these qualifications.

Scientific work in the physics, chemistry and mineralogy of ceramic materials is most desirable. But it is the specific task of the physicist, chemist and mineralogist.

It is true, however, that the general scientific training offered in ceramics is not always adequate and that the teaching of ceramic subjects may be weak, merely descriptive and lacking in that happy combination of sound theoretical and practical presentation which is so essential. There is no reason why the scientific principles underlying ceramic technology should not be incorporated in the technical studies in a logical and exact manner. That there is considerable room for better teaching in

ceramic schools is shown in the contributions by recent graduates in the JOURNAL and by the experience of research laboratories employing such assistance. There is need not only of better undergraduate teaching but also of opportunities for post-graduate study either in colleges or in research laboratories.

Technical men, properly trained in ceramics or ceramic engineering, are able to render maximum service to the industry and can maintain our literature on a level with that of modern chemical, metallurgical and mining engineering. Those who desire us to direct our activities into the channel of one science have a narrow and misleading conception of the field of ceramics, which is not a branch of chemistry any more than is mining engineering.

ORIGINAL PAPERS AND DISCUSSIONS

DESIGN FOR A FIRE BRICK PLANT[1]

By R. H. Minton

In designing a clay-working plant of any kind today three important considerations are involved.

First: To make it as nearly automatic as possible, thus reducing the amount of labor involved.

Second: To arrange the processes and routing as efficiently as possible, to make the housing compact in order to keep down the capital investment.

Third: To equip the plant with the most efficient drying and burning system possible.

In the plant shown here an attempt has been made to carry into execution these three points as far as seems possible. It is designed to use the dry-press process for plastic fire clays.[2]

Clay Storage.—The clay storage room extends full width of, and adjacent to, the manufacturing room. This storage room has two overhead tracks upon which the clays are delivered by gravity from the clay banks. An overhead electric crane operating all over the room is so arranged that a grab bucket, with automatic measuring device, will take clay from any pile in the proper proportion for the mix.

Preparation.—The mix is dumped by the crane into a hopper which feeds a wet pan. By this process all the different clays are thoroughly mixed in order to give a much greater uniformity than if the clays and grog were run through a dry pan only. Tests

[1] Received February 27, 1920.

[2] Plant of S. G. Brinkman, Fords, N. J., operating partly according to this general scheme.

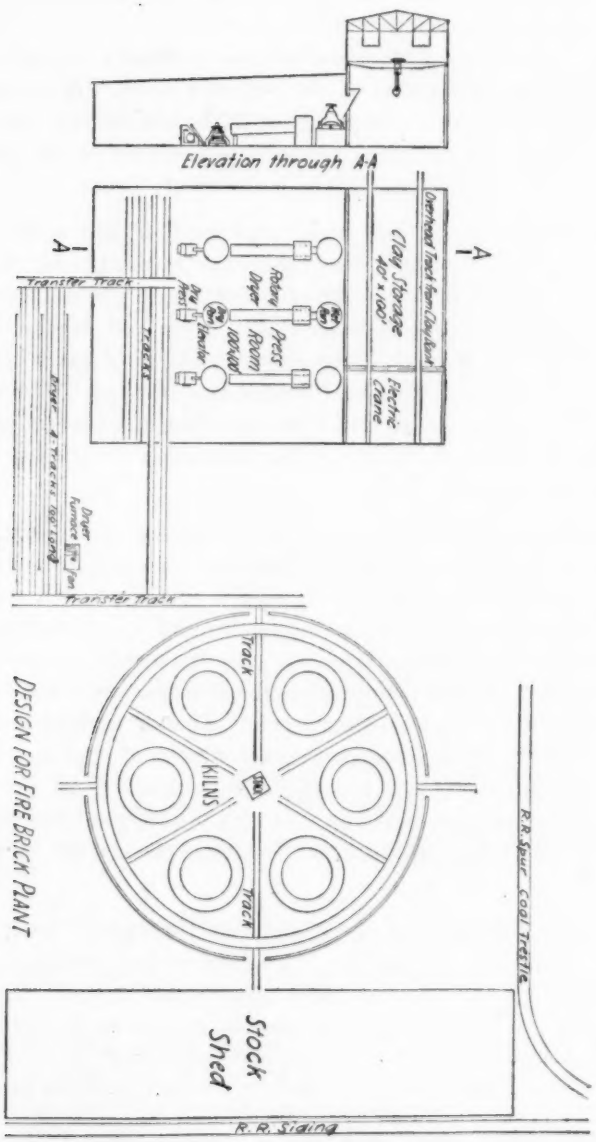

FIG. 1.

DESIGN FOR FIRE BRICK PLANT

have shown that where the various clays are thoroughly blended a superior product results.

These wet pans are designed with a stationary rim which does not turn with the pan as in the ordinary type. This rim has a portion hinged like a gate, and an automatic device causes this gate to swing inward after so many revolutions of the pan, and causes the pan to empty itself into the rotary dryer.

Rotary Dryer.—In the usual stiff-mud or soft-mud method of brick manufacture the brick are made in the plastic state and the water driven off in the dryer. By the dry-press process the wet mix is first run through the rotary dryer and the excess water driven off. The mixture is not dried to any great extent but only sufficiently to allow running through the dry pan. The mixture comes in a continuous stream from the dryer into the dry pan from which it is conveyed by an elevator to the hopper feeding the dry press. No screen is used.

Dry Press.—The dry presses have their molds equipped with electrical heating units, which eliminate the usual steam connections. These presses are also equipped with an automatic mold-filling device which permits the handling of a clay mixture with, as much as 17 per cent of moisture. By the usual dry press process the moisture content is limited to about 10 per cent, and the physical bond of the brick is rather weak. The strength of the burned brick depends upon a bonding clay, which, of course, lowers its melting point. By this process it is possible to dry-press brick having almost as much moisture as by the stiff-mud process. The resultant brick has the physical strength of those made by the stiff-mud process.

Dryer.—The pressed brick are run through a dryer to dry them sufficiently for setting. The driers are equipped with a fan connected with a waste-heat pipe extending from the tops of the kilns. Hot air for drying may be had from all burning and cooling kilns. When there is not sufficient waste heat direct heat may be had from a coal-fired furnace connected to the fan.

Kiln Room.—This plant is laid out as a unit with six kilns holding 32,000 brick each. These kilns are built in a circle around

a central stack to which all are connected. The kilns are housed in a circular building, which may be of brick with a brick crown for the roof, or it may be a steel structure. Around the circle of kilns is a transfer track with exits at the four quarters of the building. There is also another circular transfer track within the

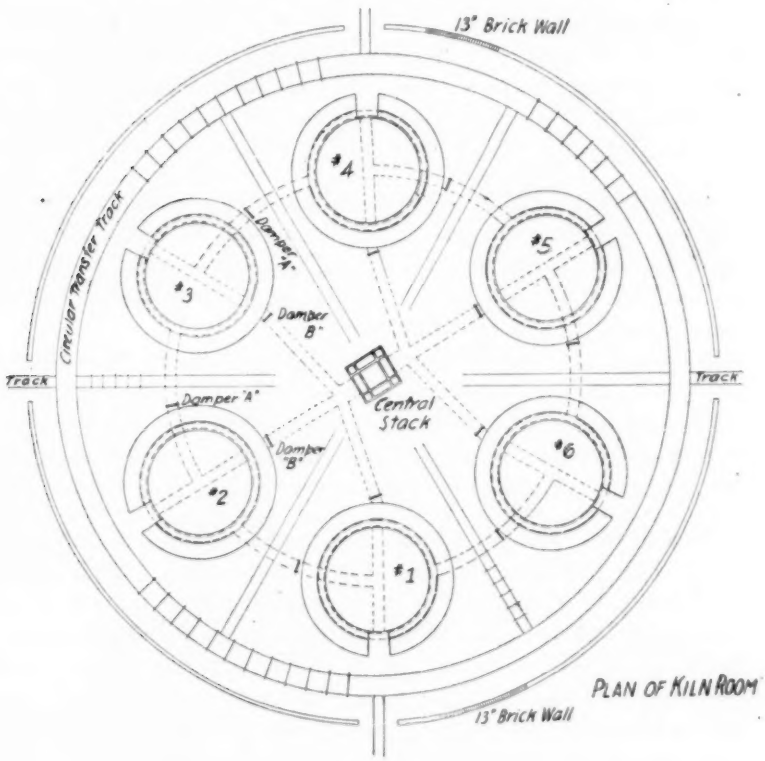

FIG. 2.

circle of kilns. This makes the coaling of the kilns quite convenient.

Firing Process.—Each kiln has a circular flue extending around it under the wall and below the fire-box ash pits. This circular flue is connected by a flue leading from the main cross flue of the preceding kiln. When firing a kiln it is possible to lead the draft directly to the stack, or by use of dampers to lead the hot gases

through one or more kilns in advance which may be ready for firing. Thus by closing damper "B" of kiln 2 and damper "A" of kiln 3 and opening damper "A" of 2 and damper "B" of 3, it is possible to utilize the hot gases from kiln 2 to watersmoke kiln 3.

Construction of Stack.—Only one stack is used for all six kilns. It is constructed in such a manner that there is an air space between the inner stack and the outer stack. This construction does away with the usual cracking of kiln stacks due to over-heating.

Construction of Kiln.—The kilns are of the downdraft type. There is a main cross-flue leading from wall to wall. Beneath this cross-flue is another flue leading from the center of the kiln to the stack. At right angles across the main cross-flue are jet flues supporting the floor blocks.

A circular flue extends around the kiln just under the wall and below the ash pits. This flue is connected by smaller flues leading into the sides of each ash pit. By this system the hot gases from a preceding kiln on fire may be led into the ash pits and through the grates into the kiln.

Fire Boxes.—One of the most important questions today for every clay man is the question of how to save fuel. Shall he use coal, producer gas or oil? Shall he install tunnel kilns at great expense? Unfortunately many manufacturers are unable, either from conditions or on account of the expense, to discard their periodic kilns and install the now efficient tunnel kilns. The problem, then, is to make the most of what they have by changing their kilns to the most efficient construction possible.

The fire box in this type of kiln is made with two sets of grates. The upper inclined grates hold the freshly supplied coal and act as a coking plate. The gas of the coal is driven off here and burns in passing over the white hot coal bed on the lower grates. It was found necessary to reconstruct this fire box some twenty times before the right proportions were obtained. In practice it is found necessary to allow a free air passage over the coal on the inclined grates. This construction seem to act as a small gas producer,

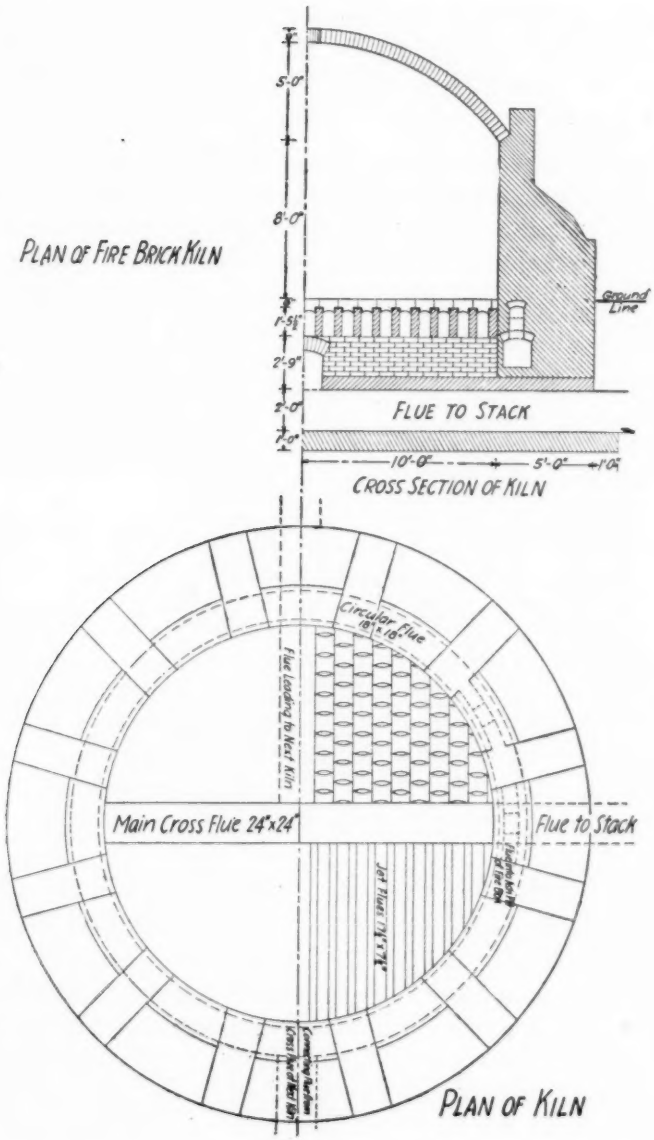
PLAN OF FIRE BRICK KILN
5'-0"
8'-0"
1'-5½"
2'-9"
2'-0"
1'-0"
Ground Line
FLUE TO STACK
10'-0"
5'-0"
1'-0"
CROSS SECTION OF KILN
Circular Flue 18"x18"
Flue Leading to Next Kiln
Main Cross Flue 24"x24"
Flue to Stack
PLAN OF KILN

FIG. 3.

and the control is such that the combustion can be made to take place in the kiln, and not part of it in the stack or open air. Even when a kiln is on full heat and directly connected to the stack no smoke ever appears.

Economy of Kilns.—These kilns holding 32,000 to 33,000 nine-inch brick, have been fired to cone 15 in four days with fifteen tons of coal. A tunnel-kiln builder states that the yearly average consumption of coal for production of five million fire brick fired in downdraft kilns was 1440 pounds per thousand, and

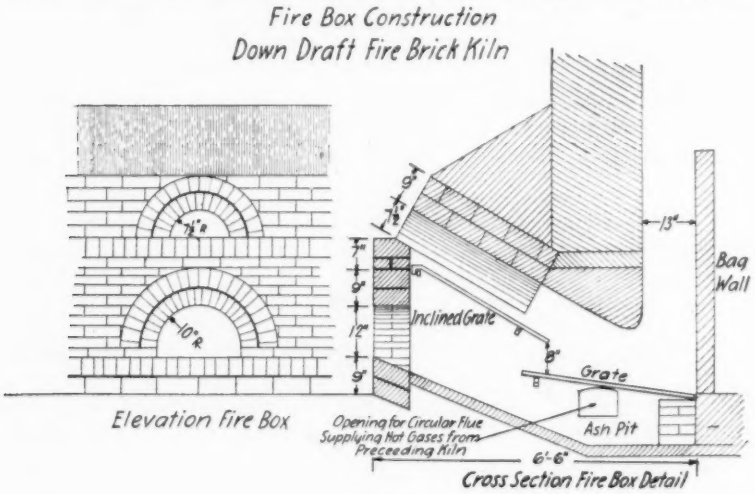

FIG. 4.

for the tunnel kiln the average was 650 pounds per thousand. With this type of kiln the average has run around 900 pounds per thousand brick.

Forced Draft in Kilns.—The question of forced draft in firing ceramic kilns deserves much more consideration than it seems to have received. We are all familiar with the evolution of locomotive boilers. The old type engine had a large, awkward stack, which has gradually been reduced by use of forced draft until the immense locomotives have little more than an opening for the escape of smoke.

With this type of kiln construction it is feasible to attach a blower to the flue leading from one kiln to the next and use forced draft under the fire grates. Burning by forced draft overcomes the variation of natural draft through weather changes and would also tend to more uniform results. With ordinary natural draft there are many currents in a kiln and the temperature is not uniform. By maintaining a pressure of an ounce, or so, in the kiln the temperature is forced into all parts, and the kiln is uniform throughout.

Dryer Construction.—The method of constructing the dryer roof is somewhat unique. It is formed with straight hollow building blocks 12 by 12 by 8 inches, with the hollows running across the width of the dryer. Through each course of tile is run an iron rod, slightly below the middle of the tile. This rod passes through plates on the outside of the tile course, and is drawn up by nuts so that it is under tension. This forms a rigid construction, capable of carrying any load, if necessary, at a low cost.

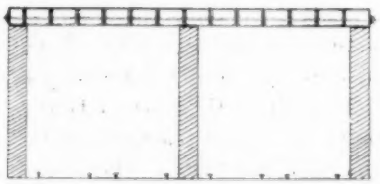

FIG. 5.—Cross section of tunnel dryer, showing tie-rod arch construction.

Conclusion.—A plant according to this design should be able to operate with a low labor element on account of the semi-automatic machinery equipment and the simple method of manufacture. Because of the efficiency of the kilns the important item of burning cost should be as low as is possible with the use of periodic kilns.

GENERAL CERAMICS CO.
METUCHEN, N. J.

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

A POSSIBLE EXPLANATION OF FAILURE UNDER LOAD AT HIGH TEMPERATURE AS DISPLAYED BY FIRE CLAY REFRACTORIES[1]

By Arthur S. Watts

The following is not offered as conclusive evidence but rather as a peculiar combination of facts which have come to my attention over a period of years and which appear all to point in one direction.

The general impression prevails that all clay refractories fail under load when a temperature of about 1300° C. is reached. This has come as a result of the work of Hereaus,[2] Bleininger and Brown,[3] and others who have carried on tests with European fire clays and American fire brick. Bleininger and Brown, page 67, in the article just cited, decide that failure at 1300° C. under a 75 pound per square inch load will result from a total flux content of 0.225 molecular equivalent or more, regardless of the content of silica but calculating the alumina as 1. The failure is pointed out as being due chiefly to an inferior bond clay and that the inferiority of the bond clay is oftener due to high flux content than to high silica content. The development of easily fusible silicates at low temperatures and the progressive solution of additonal silica and alumina with increased temperature or with a prolonged exposure to the same temperature is presented as sufficient cause for the failure of the refractory under load.

The foregoing is undoubtedly the cause of some premature failures under the conditions specified; but it has become apparent to every user of fire-clay brick that the brick begins to weaken mechanically under load at a temperature below 1300° C. regardless of how low the alkali content or how nearly the Al_2O_3-SiO_2 formula approaches that of pure kaolinite.

[1] Received Feb. 27, 1920.

[2] *Zeitschrift f. angew. Chem.*, **13**, 49 (1905).

[3] U. S. Bur. of Standards *Tech. Paper*, 7.

Bleininger and Brown[1] show a brick containing 0.81 per cent total alkali, 39.19 per cent Al_2O_3 and 56.62 per cent SiO_2, which begins to deform under load at 1291° C., although its actual fusion temperature is given as cone $31\frac{1}{2}$ (approximately 1695° C.). Another brick with 0.88 per cent total alkali, 40.42 per cent Al_2O_3 and 54.51 per cent SiO_2 begins to deform under load at 1207° C., although its actual fusion temperature is given as cone 31 (approximately 1685° C.). Another brick having 0.92 per cent total alkali, 43.41 per cent Al_2O_3 and 52.89 per cent SiO_2 begins to deform under load at 1213° C., although its actual fusion temperature is given as cone 31 (approximately 1685° C.). On the other hand, these writers show a brick containing 0.66 per cent total alkali, 19.00 per cent Al_2O_3 and 77.82 per cent SiO_2, which although its actual fusion temperature is given as cone 29 (approximately 1650° C.), *i. e.*, lower than of the preceding three, shows no tendency to deform under the load test. Of the four refractories cited, all contain less than one per cent flux. Three have Al_2O_3 and SiO_2 contents approaching the kaolinite formula and all these fail under the load test. The fourth has a low Al_2O_3 and high SiO_2 content, and stands the load test. The difference in flux is not sufficient to cause the difference in behavior and it can, therefore, only be due to either the low Al_2O_3 or high SiO_2.

Bleininger and Brown also state[2] "a clay fairly high in fluxes, corresponding, for instance, to 0.22 $RO\text{-}Al_2O_3 2SiO_2$ would be improved by the dilution with silicious material containing practically no fluxes, or even by the addition of a clean sandstone, the principal requirement being intimate blending and grinding." The advantage of reducing the flux content by adding pure SiO_2 is thus acknowledged, but no note is made of the effect of reduction in Al_2O_3 content.

The writers also make an important observation on page 62 where they observe "The hardness of burning in general is a factor worthy of consideration. Our work has shown that well-burned bricks stand up better than soft-burnt products." On page 73 "Experiments carried on by the writers have shown that

[1] U. S. Bur. of Standards *Tech. Paper* 7, pp. 52 and 56.

[2] *Tech. Paper* 7, p. 71.

harder burning has increased the strength of fire brick appreciably. The superiority of high-fired over low-fired ware from every standpoint, especially as regards change in volume when part of the furnace wall, is so striking that every effort should be made to push the maximum possible burning temperature." The hard burning is justified by the fact that the more fusible bond clays absorb some refractory flint clay and are thus improved as regards resistance to load.

A study of all the data above mentioned, has raised the inquiry in my mind, whether this weakness displayed by high alumina clay refractories is really due to the progress of pyrochemical solution or whether it can not be more properly charged to a period of physical weakness produced in the mass by the decomposition of the kaolin and the recombination of the Al_2O_3 and SiO_2 as sillimanite.

If such a change can be shown to occur at about the temperature where failure is observed this would be a logical explanation and in line with observations in other similar cases. For example, we recognize the crystallization in masses of metal as a direct cause of mechanical weakness. Also we recognize the change of crystal form in silica as an explanation of failure in this class of refractory. Why then should not the development of sillimanite be considered as the cause of failure in clay masses in which it is known to exist.

As regards the temperature of development of sillimanite there can be no doubt but that it does mature as low as 1170° C. when the mass is only commercially vitreous. This fact I proved in an investigation of paving brick a few years ago, and I presume abundant additional evidence could be obtained to justify this temperature as within the limits of sillimanite development. The temperatures at which Bleininger and Brown observed deformation were with but three exceptions above this temperature.

Furthermore, vitrification is not necessary to the development of sillimanite which has been shown by Glasenapp and others to be not a case of crystallization out of solution but a case of molecular rearrangement by which, as Glasenapp states, "All clays become crystalline at high temperature coincident with the de-

composition of the clay substance." If then the development of sillimanite is merely the product of molecular rearrangement without fusion, the mechanical failure of the mass due to this molecular change would begin as soon as sufficient temperature for such change was reached.

However, since the publication of the above statement of Glasenapp, some other evidence has developed which has a distinct bearing on the case. Zoellner conducted an investigation at cone 15 to ascertain whether all clays would produce an equal yield of sillimanite provided they contained the same Al_2O_3 content. The results of his investigation are given in the following table:

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	KNaO	H_2O	Sillimanite residue
Zettlitz kaolin.....	45.66	38.54	0.90	0.08	0.38	0.66	13.00	20.5%
Kemlitz kaolin.....	54.2	32.9	.29	.17	.13	.49	11.82	21.12
Poschez kaolin.....	45.6	39.23	.80	.20	.22	.83	13.42	22.4
Wildstein clay.....	47.7	35.7	2.2	.25	.10	3.02	11.2	2.1
Putschirn clay.....	56.0	30.0	..	Trace	.20	1.7	12.1	5.8

Thus we find three kaolins when fired at cone 15, yielding from 20 to 23 per cent sillimanite. Two ball clays, however, which have almost the same Al_2O_3 content as the kaolins but which vitrify at cone 15, yield less than 6 per cent sillimanite. Zoellner concludes that the earlier vitrification and the development of complex silicates made possible by the higher flux content is the cause of the very low sillimanite development in ball clays.

If sillimanite development is the cause of weakness in high aluminous clays around 1200° C. and if ball clays are notably free from such development, then refractories high in ball clays should display little weakness around this temperature. And this is exactly the fact which I wish to call to your attention. As the tendency to fire our white wares higher has called for more durable saggers and as the increased use of the sagger machine has demanded a plastic mass which would flow more freely than the old sagger mixes, we have resorted to the use of increasing amounts of ball clays of poor color but good refractory value. The admixture of even a moderate amount of fire clay has been found distinctly injurious even though its fusion temperature was equal or superior to that of the ball clay. The only other clay

found suitable for mixing was a highly silicious clay, as a wad clay or some such clay. A highly silicious kaolin in crude form, called "spar" is used in the east, and in Ohio a highly silicious but refractory flood plain clay is used. In both cases the saggers are far superior to anything that can be produced by the use of the best flint and plastic fire clays. The saggers containing fire clays are mechanically weak and crack after a few firings at best while the ball clay saggers if properly made seem to last almost indefinitely unless broken in handling. Limited study of fire clay saggers showing abnormal weakness apparently show high sillimanite development which is strikingly absent in saggers made from ball and wad clays, but further study and investigation is considered necessary before any positive statement can be made in the matter. If anyone has any contradictory evidence, the writer would be more than pleased to hear of and consider same.

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Discussion

Mr. R. T. Stull: The development of weakness during the transition period, or period during change of state, is well recognized. A prominent metallurgist cited to me a very interesting illustration. In manufacturing a special grade of steel, a difficulty was encountered during the rolling process. About the middle of the rolling process the steel would crumble, due to a change in physical state.

The difficulty was obviated by giving the billets a preliminary rolling, then setting them aside for a few minutes until the change was completed, then finishing the rolling process.

The period during the dissociation in the fire brick preceding the formation of sillimanite represents a period of weakness in those brick which have been previously fired at temperatures below that at which sillimanite forms in appreciable quantities. But after the sillimanite has been formed, the strength of the brick returns to a greater or less degree, which may explain the fact that brick burned to high temperatures withstand the load test better than soft-burned brick.

DR. E. S. MOORE: Speaking from the standpoint of the mineralogist and petrographer, it seems reasonable that the proportion of silica present should have a very marked influence on the relative amount of sillimanite formed. In the first place, an increase in silica tends to increase the viscosity, to retard molecular movement in the solution and to retard the development of the sillimanite, and in the second place the more silica present, the greater the tendency to form disilicates or metasilicates instead of the orthosilicate, sillimanite. These conditions are illustrated in the development of minerals in rocks.

MR. M. C. BOOZE: It is not clear whether Prof. Watts attributes the failure of fire-clay refractories to sillimanite formed during the load test or during the initial firing. If he refers to the latter, then, according to theory advanced, higher firing with an accompanying increase in crystalline sillimanite should weaken the structure and give greater deformation in the load test. This is contrary to practical results.

But little sillimanite could be formed during the load test burn since the decomposition of the kaolinite molecules and the formation of sillimanite would certainly have gone far enough during the initial burn of several days' duration that but little more would be formed during a six-hour test burn. Certainly, in the case of those refractories which are fired for a long period and at a maximum temperature as high as that received during the load test, there would be practically no further development of sillimanite during the load test burn. Yet these refractories do fail in the load test and with other things constant their deformation is a function of the bond clay used. These bricks behave under load in a way quite typical of all fire-clay refractories. According to the explanation advanced by Prof. Watts we would expect a different behavior since the strains produced by sillimanite crystallization are absent. If failure were due to molecular decomposition of the clay and the formation of crystalline sillimanite, the failure should be comparatively sharp, such as obtained with a silica brick. The typical fire-clay refractory failure shows a gradual swelling of the base and a round-

ing of the sides which means that the viscosity of the bond has been lowered and the brick has flowed under pressure.

Mellor[1] has discussed the load test as applied to high alumina clays and states that with such refractories "there does not appear to be a limit to the decrease in refractoriness under an increasing load." This he explains as being due to the fact that the melting point of alumina is decreased by pressure and which will explain the abnormal deformation observed by Prof. Watts in high alumina refractories.

MR. A. A. KLEIN: Although the formation of sillimanite as a result of clay dissociation might possibly be the cause of introducing slight strain in fire-clay bodies it is absolutely certain that this is of very little if any importance in the explanation of the failure of refractory clay bodies under load at high temperature. In the first place the conditions attending upon the formation of sillimanite are not as Prof. Watts points out analogous to crystallization in steel since there is always some liquid phase present at the temperature of sillimanite formation which tends to dissipate the strain.

Again his analogy to silica brick does not seem to be warranted. In the first place the formation of cristobalite and tridymite involves expansion due not to chemical reaction but to thermal inversion. This takes place not only in the fine groundmass of the silica brick where there is a little liquid phase present during the inversion but also in the coarse granules (phenycrysts) where the inversion proceeds inside the crystals in the absence of any flux due to impurities.

This effect is quite contrary to that noted by Bleininger and Brown (B. of S. Tech. Paper No. 7) on fire-clay bricks which had failed in the load test. On page 57 they state that "inspection of the failures shows plainly that the more refractory flint fire clay has not softened to the slightest extent. The grains have lost none of their original identity. They seemed to have slid upon each other, the bond clay behaving analogously to a lubricant. From this it follows that no matter how excellent the major con-

[1] *Trans. Amer. Ceram. Soc.*, **17**, p. 94.

stituent of the brick may be as to refractoriness, if the bond clay is too deficient in this respect the load carrying power of the product is impaired."

A close examination of the compositions cited by Prof. Watts (Tech. Paper No. 7, pp. 52 and 56) with particular reference to figure 28 where the behavior of all samples under load test are recorded shows that an apparent little difference in RO content may be of importance in causing failures. For instance composition 30 failed and 23 did not fail. Their compositions were as follows: Molecular equivalents of RO equals 0.175 and 0.15 respectively; molecular equivalents SiO_2: Al_2O_3 equals 3.6 and 3.7 respectively.

Furthermore in that portion of the field as given in figure 27 where failures were predominant they were not universal. Such a condition would be impossible to explain on the basis of sillimanite inversion as indicated below.

The temperature of sillimanite formation and the growth as well as the development of sillimanite crystals depend mainly upon the composition of the body. The relation of its formation to the temperature of burning as given in Bur. of Stand. Tech. Paper No. 80 on the constitution and microstructure of porcelain, table 4, holds only for compositions used in porcelain practice.

The data are quite different for products of low flux contents (fire-clay refractories), and the formation of sillimanite here takes place with more difficulty and at higher temperature than in bodies of porcelain composition.

Furthermore, recently we have found the development of large, well-formed sillimanite crystals resulting from kaolin dissociation at 1000° C. in the presence of a very low fusing reactive flux. This is apparently not in accord with the work of Zoellner but is based upon our experience in the microscopy of bodies containing kaolin. Zoellner's sillimanite results which depended upon differential chemical reaction are open to the same question of accurency as the values obtained by the rational analyses of clay.

Aside from this the inspection of Zoellner's analyses as given by Watts shows that the Wuldstein and Putschvin clays contain

more alkali than the kaolins. Figuring the alkali to the formulas of feldspar or mica, it is certain that the actual amounts of kaolinite ($Al_2O_3.2SiO_2.2H_2O$) present in these clays were by no means constant. It follows also that the actual amounts sillimanite produced by dissociation of the kaolinite should not have been constant.

It is our experience that products of the same composition should show substantially the same sillimanite formation under the same thermal conditions; and if this is the cause of failure, they should all fail together, which is certainly not so as shown in Tech. Paper 7, figure 28.

It follows also from Prof. Watts' theory that fire-clay brick which have greater sillimanite development, and for a definite composition this could only be brought about by greater heat treatment in burning, should show greater tendency toward failure. This is contrary to universal experience since it is well known and has been pointed out by Bleininger and Brown as well as by others, that higher burning produces harder brick which tend to give better results under the load test.

The present data indicate that in general failures under load are due to the undue fluxing of the bond clay and that the tendency toward failure can be reduced by finer grinding and blending as well as by harder burning.

MR. WATTS: Replying to the discussion of Mr. Booze, I would explain that the sillimanite must have formed during the original firing, if that firing reached the temperature of the test. However, any additional burning at that temperature or above would undoubtedly add to the sillimanite development. The proportion of sillimanite which would form during any given period is recognized as dependent upon the time and temperature employed. The cause of weakness, however, is not the sillimanite crystallization but the period of weakness caused by molecular rearrangement due to sillimanite development. The sillimanite itself, if its crystallization was sufficiently coarse to form a mattress, would theoretically add strength to a mass; and this is doubtless the case where the material is burned well beyond the

temperature at which the sillimanite forms prior to the application of the load test. Where, however, the development of sillimanite occurs at the time of the application of load, the molecular rearrangement due to its formation must cause a more or less distinct period of weakness; if the development of sillimanite is abrupt, the weakening of the mass would be abrupt, but if the sillimanite development was gradual the weakening would be gradual, which is what we observed.

Regarding the statement by Dr. Mellor, quoted by Mr. Booze, I believe that the interpretation is misleading and that Dr. Mellor intended to convey the impression that the melting point of alumina would be decreased by pressure equally applied from all directions as a physical state and not that a load placed upon the mass of alumina from one side only would lower its melting temperature.

Mr. Klein's point that the conditions attending the formation of sillimanite are not analogous to the crystallization phenomena in steel is not clear to me. The period of crystallization in steel is distinct, and any pressure applied within the temperatures of this crystallization would cause a tendency to rupture. It is reasonable to believe that if a mass of aluminum silicate undergoes a change from the amorphous to the crystalline state or that a complete molecular rearrangement occurs, such a period must necessarily be one of temporary weakness. Mr. Klein says that some liquid phase is always present at the temperature of sillimanite formation. I should like to see proof offered that this is the case when a mass of pure kaolin is heated to a temperature of cone 15, approximately 1430° C, and sillimanite develops in considerable quantity. So far as my observations have gone the change is not attended in such cases by the development of sufficient liquid phase to function as a lubricant to the crystalline particles formed. The analogy to silica brick was merely, insofar as a period of weakness exists, due to a change of physical state. In this sense I cannot understand why Mr. Klein does not see the similarity. It is not the intention of the writer to offer the theory presented in this paper as a substitute for the explanation presented by Bleininger and Brown, and he thoroughly

understands and appreciates that in a great majority of cases their explanation is the only plausible one; but in the paper presented he merely suggests that evidence points, in his judgment, to the fact that a distinct period of weakness exists in masses of aluminium silicate when they are undergoing a molecular rearrangement, due to the development of sillimanite.

The statements regarding the formation of sillimanite as regards temperature are so well understood and agreed upon that I cannot understand why Mr. Klein takes space to repeat them. I would call attention to the fact, however, that Mr. Klein is apparently more concerned with the size of the crystal than with its existence as a new constituent of the mass. The crystallization may even be sub-microscopic, and yet the period of molecular rearrangement could be expected to constitute a period of weakness in the mass. As regards the development of large crystals of sillimanite I would say that these have been for the last fifteen years produced by the intimate mixing of kaolin and some easily fusible mineral, such as boric acid. These crystals, however, are rarely encountered in refractory masses and do not concern this discussion. Their development, however, was explained by Zoellner contrary to Mr. Klein's statement. Zoellner's sillimanite data did not depend upon differential chemical reaction, as Mr. Klein states, but upon microscopic identification and chemical analysis of the crystalline material produced.

Regarding the Wildestein and Putschern clays containing more alkali, I would call your attention to the fact that Mr. Klein attempts to explain coarse sillimanite crystallization by the presence of low fusing reactive flux. The presence of an excess of alkali, which is apparently operative in the development of large crystals of sillimanite in porcelain, when fired at a proper temperature, does not yield sillimanite crystallization in these clays and in other plastic clays, so far as the writer's observation has gone. The behavior in clays is, therefore, apparently not analogous to the behavior in porcelains and Mr. Klein's data, based on studying porcelain mixtures, therefore, does not justify any general assumptions.

The most common cause of failure of clay refractories is undoubtedly the fluxing of bond clay and the finer grinding of the

bond clay would merely cause its more rapid fusion. The introduction of more refractory clay will undoubtedly reduce the distortion proportionately. The fact that such fusion does occur in a majority of cases is, however, in the writer's judgment not sufficient justification for disclaiming that the period of weakness created by the molecular rearrangement of the alumina and silica in the mass is not a factor worthy of consideration.

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NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

DATA ON THE OPERATION OF THE DRESSLER TUNNEL KILN IN THE MANUFACTURE OF SEMI-PORCELAIN DINNER WARE[1]

By Ira E. Sproat and Donald Allbright

Introduction

The data given in this paper have been obtained from tests and observations on the Dressler tunnel kiln at the Limoges China Co., Sebring, Ohio, during the nine-months period from April 1919, to December 1919.

The general principles of operation of this type of kiln are well known as they have been discussed several times before this Society. However, during about a year's travel over the rocky road of experience we have encountered a number of operating details which will probably be of interest to those who are manufacturing semi-porcelain dinner ware and are contemplating the installation of this type of kiln.

The Gas Producer

Quality of Gas.—One of the chief factors, if not the principal one, to be considered in the successful operation of the Dressler tunnel kiln is the quality of the gas and its proper control. Cool gas is desirable in the tunnel kiln, since such gas is more free from soot which, unless properly controlled, fills up the ducts, valves and burners. If carbon is allowed to accumulate in the burners, it may be the source of much trouble and consequently interfere with the proper regulation of the temperature within the kiln. It is not always possible to obtain the quality of gas desired; therefore, to offset any trouble from this source the burners should be cleaned regularly and frequently. This will prevent the accumulation of a sufficient amount of carbon to cause any trouble by cracking a burner.

[1] Received February 27, 1920.

Another feature to be considered in this connection is the distance between the producer and kiln proper. If the producer is at least 20 feet from the kiln, the major portion of the carbon in the gas will be deposited in the duct leading to the kiln where it is very easily and readily removed by the simple expedient of burning it out with kerosene.

A cool gas may be described as one graduating from a straw color to a blue, depending upon the amount of volatile matter thrown off by the coal used. A brown or black gas is a guide to bad conditions inside the producer, and when this appears the fuel bed should be raked thoroughly with some deep poking to determine the cause, which may be either too hot a fuel bed, or blow-holes or both.

In a properly operated producer, the fuel bed is always visible through the poke holes. If the gas becomes hot, a conical-shaped short flame becomes immediately visible when the poke holes are opened. Usually, this condition is the result of one of two causes.

First: Blow-holes in the fuel bed through which the steam and air pass without decomposition. Thorough combination of these with the volatile materials driven off from the coal is the normal condition when the steam and air pass through the fuel bed in such a way as to come in intimate contact with the glowing coals. When a blow-hole occurs the sides of the "channel," as it is also called, become very hot, and the gas is burned within the producer to a considerable extent. To remedy this, rake the fuel bed, increase the amount of coal, and increase the proportion of steam to air at the blower.

Second: The flowing of too great a proportion of air to steam into the producer. To cool the fuel bed proceed as in the first case, namely, rake the fuel bed, increase the amount of coal and steam.

Therefore, it can be readily seen that the quality of the gas depends largely upon the skill of the operator. Too much stress cannot be put upon the advisability of uniform firing conditions. If a coal of comparative uniform composition is used and is fired in small quantities at regular intervals and the fuel bed raked at stated periods, it will be found that very few changes will have to be made in the gas and air inlets when once properly adjusted.

The changes necessary to produce the quality of gas desired can be made by an occasional change in the amount of coal added to the producer.

Standard Conditions of Operation.—We have found that three shovels full of coal, weighing 23 pounds each, fired into the

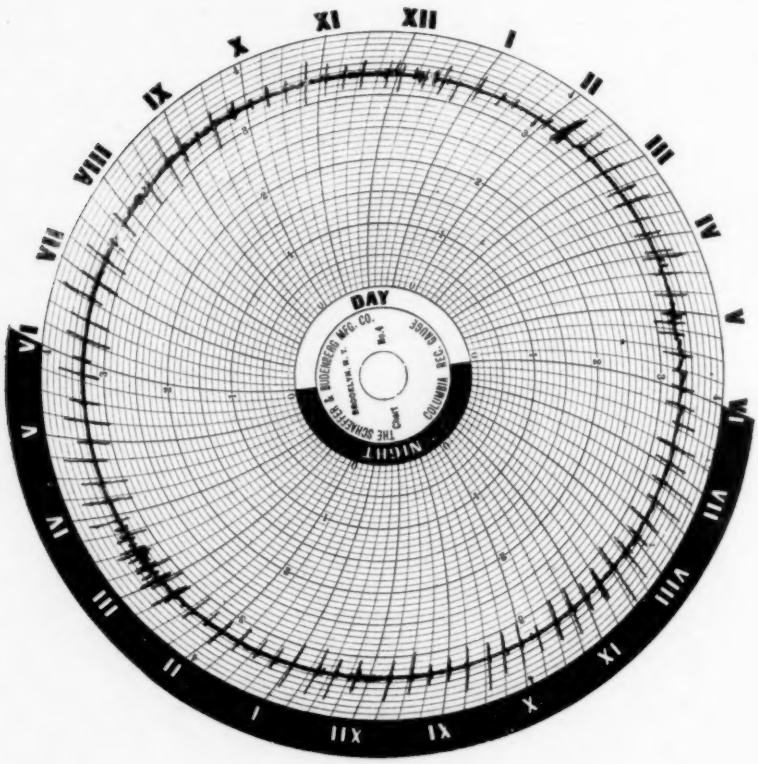


FIG. 1.

producer every 15 minutes produces sufficient volume of gas to properly operate the kiln, and that raking the fuel bed every two hours will generally be sufficient to avoid blow-holes and to distribute the fresh coal evenly over the entire fuel bed. Perhaps a still better way to rake the fuel bed is to rake through every other poke hole every hour. If these simple rules are adhered to

with precision, very little trouble, if any, will be experienced in the operation of the producer and the resulting bad effects on the uniform temperature within the kiln avoided.

The gas pressure is normally kept at 0.3 inch head of water, but this can be varied according to the requirements, such as burner openings, volume of gas consumed, etc. The chart (figure 1) is a typical pressuregraph record for 24 hours. The instrument has been set so as to be at zero pressure when the recording pen is at 3.0 on the chart. This was done so as to give more recording space and a correspondingly better and more complete record. Besides giving a record of the gas pressure this pressuregraph chart is a very good check on the time when the producer man adds more fuel to the producer, for every time the bell hopper is raised to admit a new charge of fuel the pressure drops, which is automatically recorded. These drops in pressure can be plainly seen on the chart.

The steam pressure is generally held at about 50 pounds.

Coal.—The best type of coal to use is one with a high gas content, and a low percentage of ash which has a comparatively high fusion point. The following is a typical analysis of a coal we have found to give good results.

Volatile combustible	15.88%
Fixed carbon	74.29
Moisture	2.12
Ash	7.71

B. T. U. per pound of coal, 14,150.

The Kiln

Since the results of changes in the position of the various dampers, inlets, and outlets of both air and gas supply, together with their many combinations, are far too many to be discussed in detail, as such a discussion would only tend to confuse the reader, the writers will confine themselves to a general description of the most fundamental principles of operation. Furthermore, we wish to emphasize the fact that any rule or principle of operation discussed in this paper can be treated in a very general way

only, and its proper application to a successful operation of the Dressler tunnel kiln depends largely upon the skill of the operator.

Balanced Gas and Air Supply.—One of the first things to be considered is the proportion of air to gas entering the combustion chamber. It can be readily seen that if more air is drawn through the chambers than is necessary to completely burn the gas at such a point, or points, where maximum temperature is desired, there is needless extraction of heat from the kiln. On the other hand, if too little air is admitted, combustion is incomplete and the amount of heat evolved greatly reduced. Therefore, in the manipulation of the air inlet and gas dampers to burners it is advisable to keep the following rule in mind:

"The greater the proportion of hot air to gas, the shorter the flame and the more intense the combustion, and conversely the smaller the proportion of hot air to gas the longer the flame and the less intense the combustion."

However, it must be remembered also that the successful application of the above rule depends largely upon the foresight and skill of the man in charge, for there are very distinct limitations to the length to which it can be carried. For instance, the volume of air can be increased to a point where the heat in the crown of the kiln can be withdrawn more rapidly than it can be generated, due to the fact that the velocity of the hot air in the chambers is too great and the heat is not given sufficient time to penetrate the chamber walls at the hot zone but travels on farther down the chamber. Such a condition is similar to the results of too small a volume of air to gas, which lengthens the flame and raises the temperature toward the mouth of the kiln.

Factors Affecting the Quality of the Ware

This brings us to the consideration of the factors directly affecting the quality of the ware and the application of the above general principles in obtaining the desired results. In order to facilitate the study and to produce a clearer and more concise digest of the subject, we have divided the kiln into three arbitrary zones, namely, the heating up, soaking, and the cooling zones.

The chart (figure 2) shows very clearly the three different zones, the location of the pyrometers, and the location of the cars within the kiln.

Zone 1.—The heating up zone extends from the mouth of the kiln to pyrometer 8, a distance of 164 feet. In the forward portion of this zone the moisture and organic matter is driven off while in the latter portion of the zone the ware is partially matured.

The chief and practically the only trouble that can occur in this zone is fire-cracking due to too rapid heating of the ware in the early stages. This rapid advance in temperature in the early stages is generally caused by too long a soaking zone which encroaches on the pre-heating zone. This can very readily be remedied by decreasing the volume of gas, and if this does not produce the desired results the draft can be increased until a short and intense flame is secured.

Zone 2.—The soaking zone extends from pyrometer 8 to 10 and is 15 feet long. It is in this zone that the ware is brought to full maturity, and therefore it is this zone that requires careful and consistent attention in order to produce uniform results.

The chief problem in this zone is to obtain sufficient penetration of the heat to the bottom of the cars with resulting uniformity in the porosity of the ware. There are several changes which can be made to increase the heat treatment of the ware on the bottom of the car. Perhaps the chief one is to decrease the temperature on the top of the car and at the same time increase the length of the soaking zone. This is nothing more or less than the application of the same principle that is used in obtaining a better heat distribution in periodic kilns, namely, a longer soaking of the ware at a lower temperature.

A longer soaking can be obtained also by the simple procedure of decreasing the rate at which the cars travel through the kiln. However, this decrease in rate is to some extent limited by the desired capacity of the kiln. This rate of advance of the cars has the greatest influence upon the degree of penetration of the heat towards the bottom of the car. Therefore, this is generally the first change to make, for increasing the length of the soaking

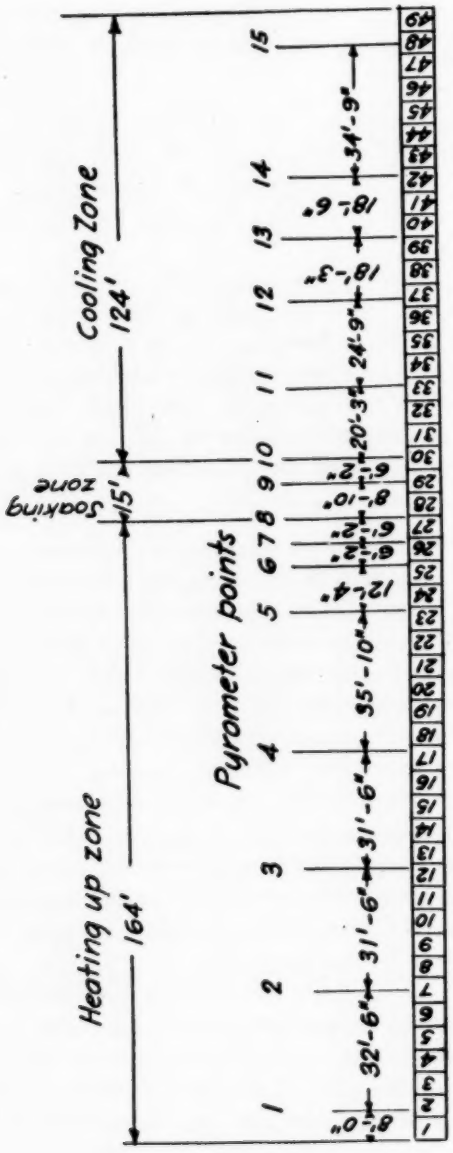


FIG. 2.—Diagram of kiln showing location of pyrometers and the relative position of the cars within the kiln.

zone is limited to a large degree by the distance the heat can be allowed to travel forward without causing too rapid heating of the ware.

Another factor which affects the degree of penetration is the manner in which the ware is placed on the cars, in saggers or in the open on shelves or racks superimposed one above the other. During the past nine months the ware has been placed in saggers in the usual way as is the custom in placing periodic kilns. The saggers are placed seven high on the cars, and each car contains on the average 60 common saggers. However, at the present

FIG. 3.

writing we have practically completed experiments with a saggerless car. These cars are simply a series of shelves six in number, six inches apart, superimposed one above the other, the supports being three-inch refractory tile. Figure 3 gives a good idea of these saggerless cars. The ware is placed on setters and then placed on the various shelves of the car.

Upon comparing the porosity of the biscuited ware from various sections of the saggerless car with tests of ware from the same section of the sagger cars directly in front and behind the saggerless car, we found that the kiln conditions which gave best results in a sagger car did not produce exactly, as uniform a product

in the saggerless car. The difference in the porosity of the ware from the top and bottom of the car was less in the case of the saggerless car; but on the other hand in nearly every instance the ware in the center of saggerless cars had a higher porosity than the ware on either side in the same horizontal plane. The porosity of the ware from the sagger cars in the same horizontal plane showed practically no variation.

Therefore, we see that under constant operating conditions the saggerless car does assist to some extent in obtaining a very even distribution of the heat between the top and bottom of the car; but when mixed cars are used this advantage is offset to some degree at least by the greater variation in the porosity of the ware from side to side of the car. This is evidently due to the fact that as the car passes into the cooling zone the saggers hold the maximum heat long enough to mature the ware on the inside. But this temporary fault of the saggerless car can easily be rectified, when all the cars entering the kiln are of this construction and the kiln has been regulated to meet the new conditions.

Probably the best feature which recommends the use of the saggerless car is the increased capacity obtainable. A sagger car on the average lists at $175, while a saggerless car lists at $325. As high as $420 worth of ware has been placed on one of these saggerless cars.

Zone 3.—The cooling zone extends from pyrometer 10 to the exit of the kiln. The temperatures of this portion in the kiln are greatly influenced by the conditions farther forward, and, therefore, are less under the control of the operator. The main thing to be avoided in this zone is a sudden drop in temperature at any one point, because this will invariably cause a large percentage of dunted ware. A gradual and uniform drop in temperature is to be desired as dunts seem to be produced far more frequently when the ware has been subjected to a sudden change in the temperature during cooling. A comparatively rapid but uniform cooling is far better than a slow and changeable rate of cooling. Sudden cold drafts are sure to produce dunts.

Standard Conditions of Operation

The following standard conditions of operation are those we have found to produce the best results with the use of cars on which the ware is placed in saggers in the usual manner. At the present writing the conditions for saggerless cars have not been permanently determined.

Car Schedule.—Every one and one-half hours a car is put into the kiln and one taken out, making 16 cars of biscuit ware

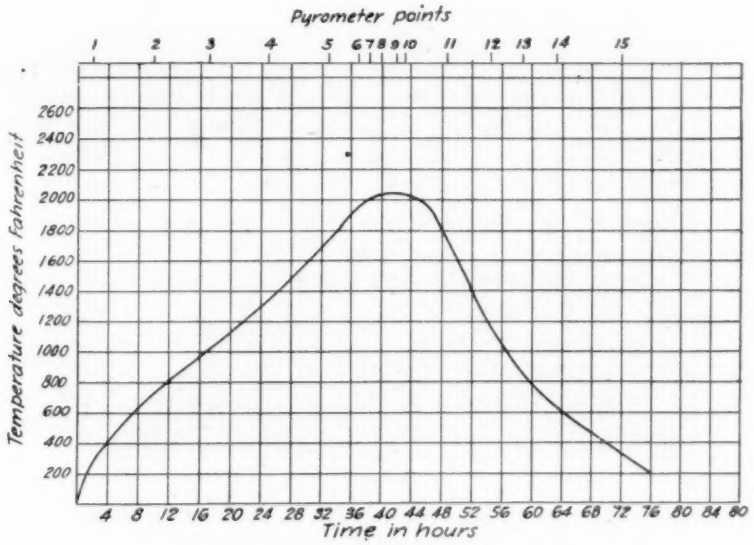


FIG. 4.—Model time–temperature curve.

every 24 hours with a combined list of approximately $2800. Figuring a car length as 6 feet 2 inches the cars move at the rate of 4 feet $1^1/_3$ inches per hour. This was the minimum rate that we could use and still maintain our desired capacity with the use of sagger cars.

Time Temperature.—With the car schedule established at one and one-half hours, very satisfactory results have been obtained with temperatures at the various pyrometer points shown in figure 4. From a study of this curve it can be readily seen

that the ware is subjected to the maximum temperature for only $3^1/_2$ hours and the entire burn is completed in 72 hours. Owing to this short soaking period at the maximum temperature, cone 9 has to be down on top of the car in order to properly mature the body.

Draft.—We have found that a draft of 0.03 inch of water at the burner points give very satisfactory results.

The results recorded below are typical of those obtained under the above standard conditions during the past several months and are being duplicated week after week.

Temperatures in the Hot Zone.—Since the uniform porosity of the ware depends upon one's ability to maintain a comparatively constant temperature in the hot zone we record in table 1 the temperatures at pyrometers 8; 9 and 10 for an average 24 hours' run.

TABLE 1

	7.30	9.00	10.30	12.00	1.30	3.00	4.30
			Day				
No.							
8.....	2060	2070	2060	2070	2070	2075	2070
9.....	2050	2050	2060	2070	2075	2070	2060
10.....	2055	2060	2060	2060	2060	2070	2060
			Night				
8.....	2070	2080	2070	2080	2075	2070	2060
9.....	2070	2070	2070	2070	2075	2070	2950
10.....	2060	2080	2070	2075	2070	2080	2060

From a study of the data in table 1, it can readily be seen that uniform and consistent results can be obtained.

Pyrometric Cones.—Besides controlling the temperatures by the use of pyrometers, cones 8, 9 and 10, placed on top of every other car, are also used. Figure 5 plainly shows the condition of cones 8, 9 and 10 for a period of four days. Again the uniformity obtainable in the kiln is plainly shown.

Porosity.—Porosity tests of the biscuited ware from all sections of the cars were made to determine the actual effect of the above conditions on the density of the ware. Table 2 gives the average per cent porosity of the ware taken from the top of the cars during a 24-hour period.

TABLE 2

Time car was drawn	Porosity per cent	Time car was drawn	Porosity per cent
6.00 A.M.	5.8	6.00 P.M.	6.3
7.30 A.M.	6.2	7.30 P.M.	6.8
9.00 A.M.	6.1	9.00 P.M.	5.1
10.30 A.M.	6.3	10.30 P.M.	5.4
12.00 Noon	6.8	12.00 Midnight	5.8
1.30 P.M.	7.4	1.30 A.M.	6.3
3.00 P.M.	7.2	3.00 A.M.	6.8
4.30 P.M.	7.1	4.30 A.M.	7.3

From the data in table 2 it can be seen that we obtain just as

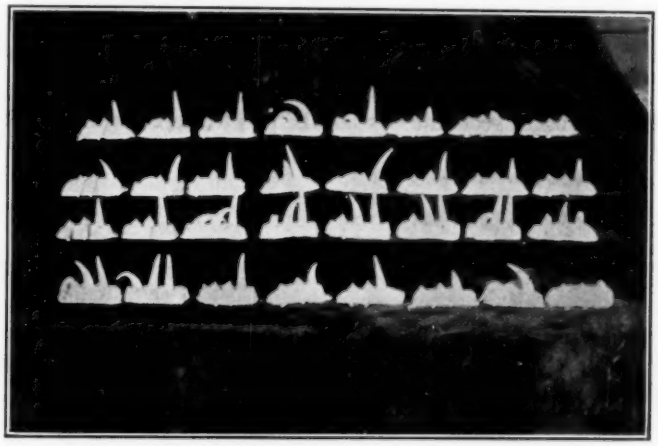


FIG. 5.—Cones 8, 9 and 10 for a period of four days.

uniform a porosity or density of the ware as would be expected from the temperatures and the conditions of the pyrometric cones as given above.

In table 3 we tabulate the porosity of the ware from the four corners of the top of two different cars. These results are typical of the conditions obtained from day to day and give an idea of the uniformity of the ware from side to side of the car. Furthermore, these results hold good regardless of the height of the horizontal plane from which the trials are taken, that is, the density of the ware on the bottom of the car is just as uniform from side to side as that on top of the car as shown by the data in table 4. As

TABLE 3

	Front. per cent	Rear. per cent	Front. per cent	Rear. per cent
Right side	7.2	7.5	6.7	6.5
Left side	7.1	7.6	6.6	6.3

has been stated before, the only appreciable difference in the porosity or density of the ware occurs between the top and bottom of the car. However, the writers wish to emphasize one point, that the slight variation in heat distribution (although just as good if not better than the average conditions in periodic kilns) as indicated from the porosity tests is not due to inability to procure a better penetration of the heat in the Dressler kiln, but the fault lies wholly with local conditions. The sagger cars decreased the capacity of the kiln to a point where it was necessary to increase the car schedule beyond the point where it was possible to obtain a better distribution of the heat. This bad feature we are certain will be eliminated just as soon as the saggerless cars are installed. The car schedule can be decreased, if necessary, and still have a greater capacity than is possible with sagger cars on a $1^1/_2$-hour schedule.

A test run was made with the cars on a two-hour schedule which allowed the ware to remain in the soaking zone for approximately 5 hours instead of $3^1/_2$. The average porosity for this run is recorded in table 4. The difference in porosity in this instance between the top and bottom of the car being only 1.1 per cent, one could not wish for better results than these.

TABLE 4

	Sagger No.	Porosity per cent
Top	1	5.0
	2	4.9
	3	5.2
	4	5.6
	5	5.8
	6	6.0
Bottom	7	6.1

Structural Features

Tracks.—Aside from the above details of operation there are several structural features which may indirectly affect the results.

Too much stress can not be placed upon the necessity of having all tracks leading to and away from the kiln laid on solid foundations and all joints made in such a way as not to give the car loaded with ware the slightest jolt as it passes over the rail joints and onto the transfer car. Especially is this imperative at the mouth of the kiln where the green ware passes over the tracks. If a car of green ware is given a number of slight bumps as it is transferred from the placing tracks to the kiln, the biscuit losses will be high. This jolting will invariably sprain the ware in the bottom of the bungs. Therefore, all tracks should be laid down with precision and care.

Ante-chamber.—In case an increase capacity over that obtained with saggerless cars on a two-hour schedule is desired we recommend the addition of about 30 feet of ante-chamber to the mouth of the kiln. The addition of this extra 30 feet would make it possible to increase the soaking zone at least 5 feet, making a total of 20 feet, which in our judgment would be sufficient to obtain a very even heat distribution under average operating conditions. Besides the ware would be brought to the maximum temperature more slowly which is to be desired as it removes the possibility of fire cracking by a too rapid expulsion of the water.

Exit-chamber.—The writers would also suggest the addition of an extra 30 feet to the exit end of the kiln. In case this is done, dunting would be entirely eliminated. The cost of constructing this extra 60 feet would be comparatively small as there would be no necessity for insulation. A 9-inch brick wall on the sides and a $4^1/_2$-inch arch overhead would be ample. This cost would be more than offset by the increased heat distribution and the decreased dunting.

Cost of Operation

It is to be regretted that the writers are unable at this time to give complete cost data on the operation of the Dressler tunnel kiln, due to the fact that a number of changes which directly affect the costs have been made and are being made today. Even though a complete unit is not in operation we can give some

data which will show the decreased cost of production by the use of the tunnel kiln.

Fuel.—We are now using $3^1/_2$ tons of coal per 24 hours for firing 16 cars of biscuit ware. Furthermore, this consumption will not be increased when saggerless cars are used as the heat now used in heating up the saggers will be used in firing the increased amount of ware. Therefore, with saggerless cars which list at $325 each, and on a $1^1/_2$ schedule, or 16 cars a day, the fuel consumption will be $3^1/_2$ tons for every $5,200 ($325 × 16) worth of ware, which is approximately what a good-sized periodic kiln lists at. But the fuel consumption of a periodic kiln is about 17 tons on the average, making a difference in coal consumption of about $2^1/_2$ tons per $1000 list. With coal at $4.25 per ton the saving will be $9.50 for every $1000 worth of ware.

Labor.—Under our peculiar present conditions of operation no saving in the labor cost has been made. But when once certain labor difficulties have been overcome and a complete unit has been installed there certainly will be a considerable decrease in the labor costs. What this decrease will be we can not say, for any figures on the labor costs that we might give would be pure and simple guess work and, therefore, useless.

Saggers.—As has been shown from our preliminary tests of the saggerless car, the cost of saggers will be materially decreased. For our first saggerless car although crudely made, has been in continuous use for over five months, being through the kiln 34 times, has had no repair, but is still in good shape and looks as if it was good for five more months. Therefore, the life of a saggerless car when properly constructed should be at least one year without repair. This means a great saving in the cost of the refractory material used for setting the ware in the kiln.

Exhaust Heat.—Another factor which will affect the comparative cost of production in the Dressler kiln *versus* the periodic kiln is the exhaust heat from the cooling pipes in the tunnel kiln. This heat can very readily be utilized in winter for heating the building and, therefore, make quite a saving in the fuel necessary to heat the biscuit warehouse, or gloss warehouse.

Conclusions

In conclusion we can conscientiously state that at the Limoges China Company it has been definitely proven beyond any question of doubt that a greater uniformity of product at a far less cost can be produced in the Dressler tunnel kiln than is possible in any type of periodic kiln in use today in the manufacture of semi-porcelain.

SEBRING POTTERY CO.
SEBRING, OHIO

NOTICE.—*Further discussion of this subject is solicited. All communications should be addressed to the Editor.*

THE COMPOSITION OF KILN GASES AND THEIR EFFECT ON TERRA COTTA GLAZES AND COLORS[1]

By F. B Ortman

Every manufacturer of architectural terra cotta is aware of the difficulties attendant upon any effort to standardize the various processes employed in his business, the very nature of which is such as to peculiarly resist efforts along this line. It not infrequently happens that attempts to reproduce former satisfactory results, fail, even though apparently all conditions remain exactly the same.

The kiln-burning is the process which usually comes in for the lion's share of the blame when such things happen, partly because it is the operation which uncovers all the errors and failures of the preceding operations, but largely because it is the process wherein direct control of, or contact with the material is, more nearly lost than in any other. Considerable has been written about terra cotta kilns, their design, construction, operation, etc.; but most of this has been directed toward the economical attainment of uniform heat-treatment, and the taking care of the major chemical changes such as dehydration, oxidation, etc., without very much regard to minor chemical reactions which may be taking place here and there throughout the kiln and which if not properly provided for or guarded against, many result in very unsatisfactory results.

It is not the intention of this paper to attempt to supply this deficiency, but rather to present a few notes on the result of an investigation on one or two of these minor changes, which are apt to be prolific sources of trouble.

Sulphuring

Nature of Trouble.—This phenomenon is one of the most frequent sources of trouble with which the manufacturer has to

[1] Received February 27, 1920.

contend, in producing glazed material. It may result in bubbling, blistering, pin-holing or scumming, depending upon the amount involved and the time and conditions under which the action takes place. The nature of the defects produced has been discussed at length by Seger (Vol. 2, page 583, Collected Writings), Burt (Vol. 2, page 139, T. A. C. Soc.) and others and will not be repeated here.

TABLE 1—SHOWING PER CENT OF SO_3 CONTAINED IN SAMPLES OF ENAMEL DRAWN FROM VARIOUS KILNS AT DIFFERENT TEMPERATURES

Temp. Degrees C	Kiln 29 Per cent SO_3	Kiln 28 Per cent SO_3	Kiln 26 Per cent SO_3
700	1.83	2.29	0.60
725	1.92	..	..
750	2.00	..	..
775	3.37	3.28	3.95
800	3.12	..	..
825	2.29	2.31	2.78
850	2.33	..	..
875	1.94	..	..

Investigation Made.—In an effort to obtain a little more information on the source, quantity, time and method of attack of this destructive agent in connection with the burning of terra cotta, an investigation was conducted over a period of several months on several different terra cotta kilns of the usual round, up-and-down draft, muffle type.

Presence of Sulphur.—Obviously the first step in the investigation was to prove the presence of sulphur in the enamel or glaze during the burning process. This was done by glazing a number of draw trials with a glaze free from sulphur and drawing them periodically up to about 875° C, or until the glaze became too hard, scraping off the glaze and analyzing it for sulphur.

The results of this analyses (table 1) showed clearly that the glaze did absorb an appreciable amount of sulphur trioxide in each of three different kilns, the maximum content (within the range covered) being at about 775° C.

Source of Sulphur.—The presence of sulphur in the glaze having been clearly indicated, the next step was to investigate the source. Since the enamel had been found to be free of sulphur

before going into the kiln (only a trace having been found on analysis), obviously the sources of same must be directly connected in some manner with the kiln-burning process. Of these there were the following possibilities:

(A) *Clay.*—The clay being used was known to contain a certain amount of sulphur both in the form of sulphates and as iron pyrites. In the case of the latter about one-half of its sulphur is distilled off as SO_2 at about red heat, the final amount not leaving until about 900° C. An average of several analyses of the clay being used at the time disclosed 0.048 per cent SO_3 and 0.038 per cent S (non-oxidized). While this would not be considered abnormally high, it is evident that the amount of sulphur driven off in a kiln of from 30 to 50 tons capacity, must be reckoned with, especially, when it is highly probable that the major portion of it leaves in a comparatively short time.

(B) *Grog.*—The importance of this material as a source of sulphur is largely dependent upon its porosity and the length of time and conditions under which it has been exposed to the weather. Freshly burned grog or vitreous grog may be considered practically free of sulphur. On the other hand, porous grog such as "overs," old fire brick, saggers, etc., when exposed to the weather may contain a considerable percentage of SO_3, no doubt absorbed from the rain which has passed through smoky atmosphere. Samples of terra cotta "overs" which have weathered for four or five years have been found to contain as high as 0.10% SO_3 on analysis.

(C) *Coal.*—The coal being used was that known as Indiana gas coal, the sulphur content of which varies greatly, but could not be considered abnormally high. An average of several analyses made at the time showed a total sulphur content of 0.80 per cent S. Theoretically, of course, in a muffle kiln (if the muffle were entirely impervious to gas), the presence of sulphur in the coal would have no effect on the atmosphere within the kiln chamber. Practically, however, as every kiln burner knows, it is impossible to exclude all the gases of combustion from the kiln chamber. This is shown conclusively by analyses of the kiln gases for sulphur (see table 2), where appreciable amounts of SO_2 are found present at the very early stages of the burn—200° C to 300° C—

or long before the first of the sulphur is distilled from the clay. The only possible source of this sulphur is from the products of combustion. That we have then, to reckon with the sulphur in the coal, there can be no doubt.

Quantity of Sulphur.—There exists then these two main sources of sulphur, *viz.*, clay and coal. The next logical step in the investigation was to determine, if possible, quantitative relationship in the sulphur content of the kiln gases, from one stage to another of the burn, as influenced by these two factors, with a view of adopting corrective measures where possible. The first efforts along this line consisted of an estimation of the SO_2 in the kiln gases and combustion gases, periodically during the burn.

Bromine Absorption.—The method adopted was to draw a volume of five gallons of gas in each instance, allowing same to bubble through a series of flasks containing bromine water forming H_2SO_4, which was later precipitated as $BaSO_4$ and calculated to milligrams of SO_3 per 5 gallons of gas. These samples were drawn simultaneously from the kiln chamber, and from the flue gases, in order to determine what relationship, if any, might exist between the sulphur content of the gases from the two sources.

Typical results of these experiments, which were conducted on several different kilns are shown in table 2, for a coal-fired kiln and table 3 for a producer-gas fired kiln.

TABLE 2—SHOWING MILLIGRAMS OF SO_3 PER 5 GALLONS OF KILN GAS AND COMBUSTION GAS AT VARIOUS TEMPERATURES OF TYPICAL BURN—DIRECT COAL-FIRED KILN

Temp. Degrees C	SO_3 in muffle mmg. in 5 gal.	SO_3 in flue mmg. in 5 gal.
100	..	1.064
200	..	10.000
300	1.270	..
400	3.260	8.580
500	0.789	22.780
600	0.861	5.733
700	7.100	27.570
800	3.780	2.400
900	27.570	4.460
1000	19.950	9.950

TABLE 3—SHOWING MILLIGRAMS OF SO_3 PER 5 GALLONS OF KILN GAS AND COMBUSTION GAS AT VARIOUS TEMPERATURES OF TYPICAL BURN OF KILN FIRED WITH PRODUCER GAS

Temp. Degrees C	SO_3 in muffle mmg. in 5 gal.	SO_3 in flue mmg. in 5 gal.
100	...	...
200	None	5.3
300	Trace	0.82
400	Trace	4.98
500	3.2	12.53
600	None	2.13
700	None	2.13
800	2.4	11.87
900	15.86	3.78
1000	...	...

From these it will be seen that the attempt to establish a quantitative relationship between the SO_3 in the flue gas and that in the kiln chamber for the temperatures below red heat was only partially successful. Generally speaking, the curves would follow the same general trend, but the relationship is not at all decisive. It would hardly be expected to be otherwise, however, as during this time all trial holes are open and the kiln chamber is well ventilated. Table 2 does show, however, as pointed out on page 479, that SO_3 is present in the kiln chamber long before any sulphur leaves the clay

Another interesting fact is brought out by comparing the results on a direct coal-fired kiln (table 2) with those on a producer-gas-fired kiln (table 3). Note that below 900° C, when all the sulphur leaves the clay, the quantity of SO_3 in the kiln seems to be considerably less for the producer gas-fired kiln than for the direct fired kiln. This difference was apparent on every producer gas-fired kiln examined, and is probably due to the more uniform-firing conditions and muffle wall temperatures which obtain with the former method. In direct firing there is a sudden cooling of the muffle walls each time a fresh charge of coal is fired, which tends to open up the joints and cracks more than usual. Coincident with this, the flue spaces are all crowded or chocked with excessive volumes of hydrocarbons and other volatile gases from the coal causing an abnormal pressure inward at this particular time, which results in excessive infiltration of the gases of com-

bustion. That this condition exists, was demonstrated a number of times by analyses of samples taken at different times with respect to the time and manner of firing. In the gas-fired kilns, obviously it does not obtain.

Lime Absorption.—In order to get still further information on the relative intensity of the suphuring action during the progress of the burn a second series of experiments was conducted as follows: A small sample of hydrated lime was introduced into the kiln chamber at a distance of about 15 inches from the muffle at the beginning of the burn and was withdrawn when the kiln reached 100° C, and a fresh sample substituted and left till 200° was reached, when another sample was introduced, and so on throughout the entire period of the burn. Each sample was then analyzed for SO_3. It was believed that from the beginning up until the glaze was fused the rate of absorption of SO_3 by the lime would be indicative of, or correlative with, the action of the same gas (SO_3) on the glazes.

TABLE 4—SHOWING AMOUNT AND RATE OF ABSORPTION OF SO_3 BY HYDRATED LIME DURING TYPICAL BURN

Hrs.	Temp. Degrees C	Per cent SO_3 in sample	Rate of absorption, per cent in 10 hrs.
12	100	0.14	0.116
32	400	.26	.37
43	500	.80	.90
49	600	.83	1.40
55	700	.83	1.40
65	800	3.92	3.92
71	900	8.01	7.30
$85\frac{1}{2}$	1000	14.13	14.00
99	1050	14.3	11.0

TABLE 5—SHOWING SQUARE INCHES OF VENTILATING OPENINGS, TOP, BOTTOM AND TOTAL, FOR SAME BURN AS IN TABLE 4

Time interval	Temp. interval °C	Sq. in top	Sq. in bottom	Total
0 to 47 hrs.	0° to 570°	276	190	476
47 to 57 hrs.	570° to 720°	84	190	274
57 to 68 hrs.	720° to 830°	20	190	210
63 to 74 hrs.	830° to 890°	20	100	120
74 to 84 hrs.	890° to 980°	20	10	30
84 to 95 hrs.	980° to 1030°	26	10	36
95 hrs. to finish	1030° to 1050°	26	0	26

From the quantity absorbed by each sample *a rate of absorption* was then computed in terms of per cent in 10 hours, and a typical result given in table 4.

Kiln Ventilation.—At this point it became evident that the method of ventilating the kiln chamber must necessarily have a very important effect on the extent of sulphuring action which takes place, and a study was made of the ventilating schedule of the same kiln. The only means available for expressing this ventilation, in quantitative terms, was in computing the area of the openings into the kiln chamber during the burn. These openings were divided into two classes—the bottom openings, through which fresh air was admitted, and the top or crown openings, through which the kiln gases were expelled. Table 5 shows the result of this computation. In order to facilitate the study of these conditions and their relation to each other chart 1 was prepared, on which, in addition to the usual time-temperative curve, are plotted curves representing the *rate of absorption* of SO_3 by lime (per cent in 10 hours), and the square inches of openings, bottom, top and total for ventilation.

Effect of Ventilation on SO_3 in Kiln.—A study of these curves brings out several interesting points.

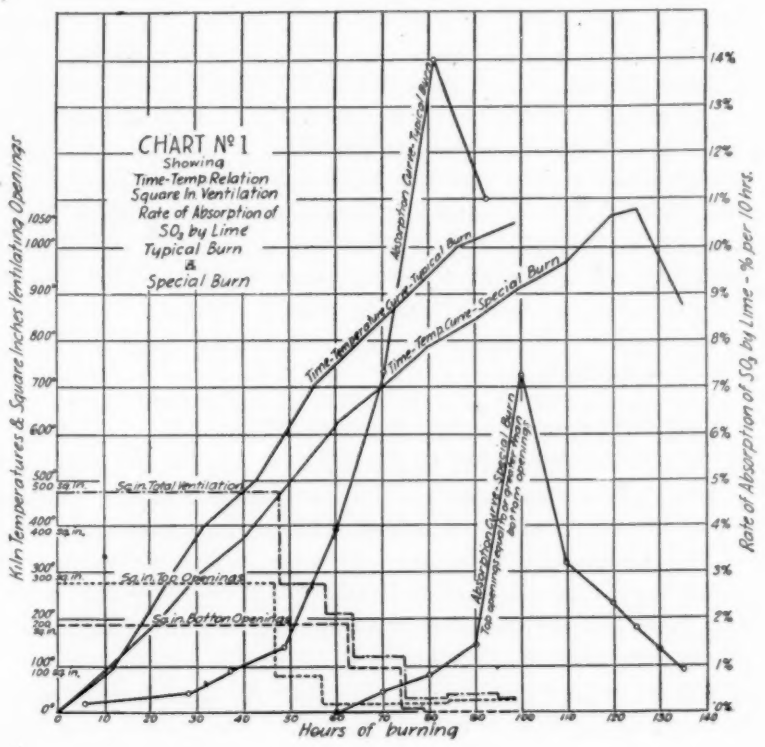
First: It is evident that the amount of SO_3 absorbed prior to the time the clay begins giving off its sulphur is almost negligible in amount, in this instance. If, however, condensation were to take place during water smoking an appreciable amount of sulphuric acid would be deposited.

Second: It is important to note that as the ventilating curves drop, the absorption curves mount. It is not to be inferred that the *former* is the *whole* cause of the latter. After red heat is reached the rapid distillation of the sulphur from the clay would greatly influence the rise in the absorption curve, independent of the ventilation. It is clear, however, that in this particular instance the ventilation is sharply reduced at a very unfortunate time, and it seems reasonable to conclude that the rate of absorption would have been kept very much lower if such had not been the case.

Third: It would seem that the effective ventilating openings would be those in the crown, and that, therefore, they should always

be kept equal to or greater than the bottom openings. In this instance after forty-eight hours the reverse is true.

Numerous experiments were then conducted with a view to reducing the amount of sulphur present by revising the ventilating schedule. These were only partially successful, however, as indicated by curve on chart 1, owing to encountering very serious



practical difficulties in maintaining satisfactory and uniform progress with the kiln, when the ventilation was carried too far. Weather and other variable conditions renders it impossible to predict in advance, in any except the most general terms, what the ventilating schedule of any particular kiln should be. The dangerous periods having been determined, it becomes the kiln burners problems on each kiln to provide the maximum ventila-

tion at these times, with a minimum of detriment to the kiln's progress. One point, however, was very clearly established, *viz.*, the necessity of adequate stack draft and flue capacity so that any difference in pressure that may exist between the kiln chamber and the flue will be exerted *outward* rather than *inward*.

Effect After Glaze Fusion.—During the course of this investigation the question arose as to whether the presence of SO_3 was destructive after fusion of the glaze. To determine this, a small, freshly glazed unburned trial was enclosed with a previously burned trial of the same glaze, in a closed sagger into which were also introduced considerable pyrites grains. The piece being burned for the first time was entirely ruined, while the previously burned piece came out unchanged, from which it would seem that after fusion of the glaze has taken place, the SO_3 has little or no effect, except of course, in the event that all of the gases have not been previously expelled from the body, or that conditions become reducing causing glaze to liberate sulphurous acid previously absorbed.

Conclusions.—A study of the data obtained by these experiments would seem to justify the following conclusions:

First: That there exists within the kiln chamber, in contact with the ware, an appreciable amount of SO_3 gas practically from start to finish of the burn.

Second: That the source of this is from a leakage of combustion gases through the muffle wall, up until about red heat when the sulphur begins to distill from the pyrites in the clay.

Third: That owing to the excessive ventilation prevailing at the beginning of the burn, the SO_3 is removed rapidly and does little damage.

Fourth: That after the glaze has fused it is not easily susceptible to chemical action of SO_3 upon its surface.

Fifth: That the danger zone, therefore, lies between red heat and the time of fusion of the glaze, and is particularly troublesome because the sulphur being distilled as SO_2 from the pyrites in the clay encounters a moist atmosphere due to the dehydration of the clay forming H_2SO_4 and at a time when the ventilaton is apt

to be sharply reduced by the closing of trial holes and crown openings.

Sixth: The sulphuric acid gas thus formed may be taken up by the glaze, either by physical absorption or chemical combination or both, and exert its destructive action in any of the following manners:

(A) Upon fusion of the glaze, SO_2 may be displaced by SiO_2 and escaping as a gas cause blisters. (Seger's Collected Writings, Vol. 2, page 647.) The extent of this action would be influenced by the silica content of the glaze and its tendency to dissolve silica from underslips or body. Seger found that a bi-silicate would hold 4 per cent of H_2SO_4 in solution while a tri-silicate would hold only 2 per cent. There is, therefore, a certain amount of SO_2 and O to be expelled from the glaze saturated with H_2SO_4 whenever that glaze takes up any silica from the body or underslip.

It is probably not necessary, however, that the glaze be saturated with sulphates, in order that SO_2 may be given off, especially if the kiln atmosphere becomes reducing. That such may be the case especially toward the end of the burn will be shown later, and no doubt herein lies the explanation of occasional blistering troubles. The glaze during the progress of the burn may have absorbed considerable H_2SO_4 from the kiln atmosphere but still be well below its saturation point. Fusion takes place and the glaze remains tranquil as long as oxidizing conditions prevail. However, if the kiln atmosphere then becomes reducing, especially at that high temperature, the H_2SO_4 and other sulphates are broken up and SO_2 and O in escaping, or attempting to escape, through the molten glaze form blisters or produce a scummy appearance.

(B) The sulphuric acid may displace boric acid (B_2O_3) from glazes containing same.

(C) H_2SO_4 may react with coloring oxides and other fluxes present, thus preventing maturity necessary for proper development of desired color and texture.

Seventh: The chances of trouble in this period may be very much lessened by:

(A) Providing the maximum ventilation possible consistent with satisfactory progress of the kiln.

(B) Firing so as to avoid choking the flues with large volumes of gas.

(C) Maintaining adequate secondary air supply in the fire boxes.

(D) Maintaining adequate stack draft and oxidizing conditions throughout.

Effect of Reducing Conditions

The necessity for maintaining oxidizing conditions through the burn is so well recognized by the terra cotta manufacturer that he is apt to take it for granted that his kiln atmosphere is always safely oxidizing. Such, however, may not prove to be the case, and an examination in connection with trouble such as color variation on both glazed and standard material, fading or loss of color on glazes, occasional blistering or scumming, etc., may disclose that his kiln atmosphere is quite frequently apt to be deficient in oxygen.

During the course of the above investigation frequent Orsat analyses were made of both the combustion gases and the gases within the kiln itself. While results of these analyses would vary somewhat from one kiln to another or with weather conditions for the same kiln those shown on chart 2 indicate the general tendency, which is to approach dangerously close, and in some cases obtain, reducing conditions the last few hours of the burn.

Numerous experiments were made in the method of firing, of introducing the secondary air in the combustion gases, of ventilating the kiln chamber proper, etc. While some improvement was noted as a result of careful study of these conditions, uniformly satisfactory conditions were not obtained until the stack draft was decidedly increased by raising and enlarging the stacks.

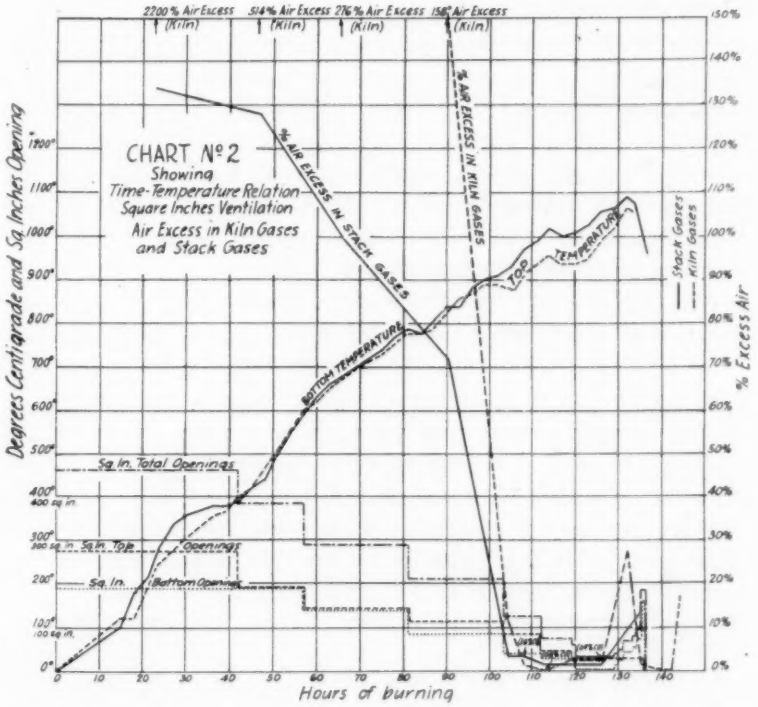
The details of these experiments and the resulting data have been omitted for brevity, but they brought out very clearly the following interesting points:

First: That it is impractical to depend entirely upon direct admission of air through trial holes or other openings for main-

tenance of oxidizing conditions, without retarding the progress of the kiln beyond practical limits.

Second: That after closing of all the trial holes and other openings into the kiln the oxygen is consumed very rapidly.

Third: That the oxygen is consumed much faster when the gases of combustion are allowed to become reducing or near reducing.



Fourth: That once the oxygen has been exhausted in the kiln chamber it is very difficult if not impossible to re-establish oxidizing conditions by admitting air into the combustion gases.

Fifth: That it is highly essential, therefore, that the combustion gases be kept safely oxidizing throughout, particularly after the trial holes are closed.

Sixth: That the setting up of reducing conditions, particularly after the glaze has fused may produce blistering, scumming, etc.,

on glazed work, by reason of reduction of sulphates previously absorbed and liberation of $SO_2 + O$ through the molten glaze.

Seventh: That while the kind of coal, method of firing, construction of fire box and secondary air supply, all have an important bearing on the maintenance of this condition, the first and most important factor is an adequate draft, without which, in the ordinary up-and-down draft muffle kiln, occasional reducing conditions are inevitable.

NORTHWESTERN TERRA COTTA CO.
CHICAGO, ILL.

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

FISH-SCALING*[1]

By J. B. Shaw

Fish-scaling is a defect very common in sheet steel enameling and practically unknown in any other connection. It is seldom encountered in enameling very heavy steel or cast iron articles. It presents itself in the form of small pits resulting from a speck of ground coat enamel jumping off, usually leaving the bright steel exposed. These pits are usually semi-circular in shape and may be as large as one-fourth inch in diameter. Two general types of fish-scaling are commonly recognized. In one the pits are very small, half the size of a pinhead or less, and are very numerous, covering nearly the entire surface. In the other type, the pits are larger, one-sixteenth to one-fourth inch in diameter, and are not so numerous.

If the ware has much tendency to fish-scale, the defect will usually present itself soon after the first coat is burned; but in case there is little tendency to fish-scale, it is liable to develop if the ware is allowed to stand some length of time after burning the first coat before applying the second. It may not present itself until the ware is run into the furnace for burning the second coat of enamel, when a snapping sound, accompanied by flying chips and black spots on the ware, give notice that the ware is ruined.

Fish-scaling is purely a ground coat defect and very rarely occurs after a second coat has been burned on the ware. It is much more common on heavy gauge (20 to 16) steel than on the lighter gauges (26 to 20). This defect must be sharply distinguished from blistering, which is also quite common in steel enameling and invariably results from impurities rolled into the steel.

* Received February 27, 1920.

[1] By permission Ingram-Richardson Co.

Another common defect in steel enameling somewhat resembling fish-scaling is the pitting which comes on the ground coat, giving it a scabby appearance. This defect is due to use of improper tempering agents which cause rusting under the ground coat in drying, the rust spots reacting vigorously with the enamel in burning, resulting in a spot having the appearance of iron scale. This defect can generally be entirely eliminated by tempering the ground coat with borax in the mill or tub.

In spite of the common occurrence and resultant high losses due to fish-scaling, the subject has received very little serious attention on the part of scientific investigators.

The following outline covers the preliminary experiments in an investigation undertaken by the writer in behalf of the Ingram-Richardson Company. Circumstances beyond our control forced us to stop before arriving at final conclusions, but it is believed the data obtained, point strongly to certain facts hereinafter stated. It may, at least, stimulate some one to further investigation, resulting in benefit to the industry.

Making and Applying Enamels

Object.—The object of the experiments here outlined was to determine how far and in what respect the composition of the ground coat affected fish-scaling.

Ground Covered.—The series of enamels was outlined to cover a wide field of compositions of ground coats of probable value. Silica, alumina and boric acid vary between wide limits. Lead, which is not commonly used, is introduced and fluorspar varies quite widely. Twenty-five frits were made and each frit given five different mill treatments, making in all one hundred twenty-five enamels.

These additions were independent of other additions of raw material mentioned, such as clay, etc. This made a total of 120 enamels, 5 enamels being made from each of the 24 frits.

Preparation.—The frits were all made in crucible batches of about 700 grams. They were ground dry to pass a 40-mesh screen. Those containing lead ground very much more easily

BATCH WEIGHTS

No.	Feld-spar	Flint	Borax	Soda	Niter	Fluor-spar	Lead oxide	Cobalt oxide	Man-ganese dioxide
1.....	84	54	76.4	30	8.5	16	0	2.5	8.7
2.....	84	54	152.8	8.5	8.5	16	0	2.5	8.7
3.....	84	54	76.4	30	8.5	0	44.6	2.5	8.7
4.....	84	54	152.8	8.5	8.5	0	44.6	2.5	8.7
5.....	84	6	76.4	30	8.5	16	0	2.5	8.7
6.....	84	6	152.8	8.5	8.5	16	0	2.5	8.7
7.....	84	6	76.4	30	8.5	0	44.6	2.5	8.7
8.....	84	6	152.8	8.5	8.5	0	44.6	2.5	8.7
9.....	168	0	76.4	13.8	8.5	16	0	2.5	8.7
10.....	168	0	152.8	0	8.5	16	0	2.5	8.7
11.....	168	0	76.4	13.8	8.5	0	44.6	2.5	8.7
12.....	168	0	152.8	0	8.5	0	44.6	2.5	8.7
		clay							
13.....	84	38.7	76.4	30	8.5	16	0	2.5	8.7
14.....	84	38.7	152.8	8.5	8.5	16	0	2.5	8.7
15.....	84	38.7	76.4	30	8.5	0	44.6	2.5	8.7
16.....	84	38.7	152.8	8.5	8.5	0	44.6	2.5	8.7
		flint							
17.....	84	34	76.4	30	8.5	16	44.6	2.5	8.7
18.....	84	34	152.8	8.5	8.5	16	44.6	2.5	8.7
19.....	84	6	76.4	30	8.5	16	44.6	2.5	8.7
20.....	84	6	152.8	8.5	8.5	16	44.6	2.5	8.7
21.....	168	0	76.4	13.8	8.5	16	44.6	2.5	8.7
22.....	168	0	152.8	0	8.5	16	44.6	2.5	8.7
		clay							
23.....	84	38.7	76.4	30	8.5	16	44.6	2.5	8.7
24.....	84	38.7	152.8	8.5	8.5	16	44.6	2.5	8.7

1-A, 2-A, etc. = 10 per cent flint added to 1, 2, etc.
1-B, 2-B, etc. = 20 per cent flint added to 1, 2, etc.
1-C, 2-C, etc. = 10 per cent calcined kaolin added to 1, 2, etc.
1-D, 2-D, etc. = 20 per cent calcined kaolin added to 1, 2, etc.

than the others and were more finely ground. German *V* clay was made into a slip and added in this form just as the enamel was prepared for dipping. All mixtures were ground together in a mortar, 8 per cent clay and 3 per cent boiled borax being constant. Additions of flint and calcined clay were ground in a mortar with the frit. In some cases these mixtures were not sufficiently well ground, and particles of raw material made the finished enamel rough. In no case was this serious enough to spoil results.

EMPIRICAL FORMULAS

No.	$KNaO$	CaO	PbO	Co_3O_4	MnO_2	Al_2O_3	SiO_2	B_2O_3
1	0.68	0.20	0.0	0.02	0.10	0.15	1.8	0.40
2	...	...	...	....	...	...	...	.80
3	...	0	.20	...	...	...	...	.40
4	...	.20	0	...	...	...	...	.80
5	...	.20	0	....	...	...	1.0	.40
6	...	...	...	....	...	...	...	.80
7	...	0	.20	....	...	...	...	.40
8	...	...	...	....	...	...	...	.80
9	...	.20	0	....	...	.30	1.8	.40
10	...	...	...	....	...	...	...	.80
11	...	0	.20	....	...	...	...	.40
12	...	...	...	....	...	...	...	.80
13	...	.20	0	....	...	...	...	.40
14	...	...	...	....	...	...	...	.80
15	...	0	.20	...	...	...	...	.40
16	...	...	...	....	...	...	...	.80
17	.57	.17	.17	.016	.08	12.5	1.5	.33
18	...	...	...	...	...	...	...	.66
19	...	...	...	....	...	...	0.84	.33
20	...	...	...	....	...	...	0.84	.66
21	...	...	...	....	...	2.5	1.5	.33
22	...	...	...	....	...	2.5	1.5	.66
23	...	...	...	....	...	...	1.0	.33
24	...	...	...	....	...	...	...	.66

Trials.—All enamels were applied by dipping on 16-gauge and 26-gauge flat sheets and on small basins made of about 24 gauge. Some of the enamels were applied to American ingot iron.

Burning.—All trials were burned in a small muffle which was hotter at one end than the other. Because of this it was quite impossible to get the same heat on both ends of a sheet. This proved quite satisfactory however, because it gave over burning, good burning and under burning of the same enamel on different parts of the same sheet, which facilitated studying of the results.

The temperature of the muffle was regulated so that it averaged as nearly as possible to 900 degrees C, or 1650° F. The time required to burn the samples under these conditions varied from 2 to 4 minutes, depending upon the weight of the steel and fusibility of the enamel.

Results

Fusibility.—All enamels with high boric acid and high lead are decidedly more fusible than the others.

The softest and best looking enamels are Nos. 8 and 16. Many of these enamels look good as ground coats.

High alumina hardens the enamel slightly, but no important difference can be noted between those high and low in Al_2O_3.

Addition of silica (flint) in the mill hardens the enamels very materially.

Addition of calcined kaolin not only hardens the enamels but gives them a dead surface and makes them burn off badly. All enamels marked C and D are decidedly inferior.

General Appearance.—All enamels containing the highest amount 0.80 of boric acid look best. Numbers 5-7-11-15-19 burn off in spots. Others might have done this under other conditions; but this seems to indicate that high lead and low boric acid is a bad combination. This same defect persists when flint is added to these frits. On account of this defect, the following enamels are ruled out, 7, 11, 15, 7A, 11A, 15A, 19A, 11B, 15B, and 19B. Number 1 did not give good results either with or without flint; it was too coarsely ground, which might account for its appearance.

Burning Off of Edges.—This defect is not serious in any case; it is slightly worse on the light steel and is somewhat less noticeable on enamels containing raw flint than those containing none. The low temperature at which these trials were burned probably saved the edges of many of them.

Fish-Scaling.—After allowing the trials to stand for a day, some of each enamel were placed in a vessel and subjected to rapid change of temperature by running first hot and then cold water over them. This was repeated several times, the object being to produce fish-scaling if possible. After standing for one year, only five enamels show any fish-scale at all, these being as follows: No. 12 on Armco and Bessemer where apparently perfectly burned; No. 12A on Armco and Bessemer where burned correctly

but slightly worse where underburned; No. 12B on Armco and Bessemer and open hearth (wash basin), where properly burned; No. 11, on Bessemer where properly burned; No. 11A, on Bessemer where properly burned.

A point of interest here is that 12C and D have not yet developed fish-scale. Number 12 on Armco developed fish-scale the day after burning. Aside from these cases, no fish-scaling is yet in evidence. It will be noted that 11 and 12 are high in alumina and silica and both are lead enamels. Number 12 is probably as good an enamel as any in the lot so far as general appearance goes, while No. 11 has been ruled off because of burning off in spots.

Effect of Flint.—The addition of flint hardens the enamel in every case; it would probably prevent the burning off of enamel on ware having this tendency, as for example, cooking ware having ears or handles. All enamels here which are good without flint are good with as high as 20 per cent.

Effect of Calcined Kaolin.—This has not been beneficial in any case and in most cases has proven detrimental insofar as the appearance of the enamel is concerned. It acts similar to flint in hardening the enamel and further tends to cause the enamel to burn off before it is properly burned. It is probable that it affects fish-scaling, samples C and D, not yet having developed this defect. So far as observations thus far made are concerned, there is not likely to be any beneficial results derived by the use of calcined kaolin.

The results obtained in the laboratory were surprising. It was expected that a majority of the enamels would show fish-scaling, but after standing a year and a half, only five of the enamels prepared in the laboratory show it. This, in spite of the fact that the enamels were applied in thick and thin coats, on different grades of heavy and light steel, and burned to various degrees of maturity in order that every opportunity might be afforded for developing the defect under consideration.

Results Obtained in a Factory

After studying the results of the laboratory experiments, the following formulas were run in the factory in 500-pound batches: Nos. 4-4B, 6-6B, 8-8B, 10-10B, 12-12B, 16-16B, 20-20B, 23-23B.

These enamels all give nice, smooth ground coats when made up in the regular factory practice; but the point of chief importance is that while, after standing a year and a half only two of them, 12 and 16, show any fish-scale on trials made in the laboratory, everyone of them develops some fish-scale as made in the factory and applied to 18-gauge steel. Some are very bad; others show only a slight amount. Number 23 is the best in this respect, and burned to a very smooth ground coat. Even it, however, showed a slight tendency to fish-scale.

Conclusions

The results obtained in the laboratory would lead to the conclusion that the chemical composition of the enamel has very little bearing on the subject of fish-scaling. When the laboratory results, where no fish-scaling is obtained, are considered in the light of the factory results, where all of the formulae show fish-scaling, the above conclusion would seem to be greatly strengthened. If it is established that the chemical composition has little bearing on the cause and control of fish-scaling, that in itself represents a long step toward the solution of the problem.

If the chemical composition of the enamel is eliminated, what other source for the trouble exists? Several might be mentioned. 1. Composition of the steel is frequently blamed. 2. Cleaning and preparation of the steel.[1] 3. Mechanical manipulation in applying the enamel. 4. Fritting and preparation of the enamel. 5. Burning the enamel. While all of these have been given by different manufacturers as contributory causes, none of them so far as the writer knows, have been seriously studied in a systematic manner, with a view to proving the contention.

Treischel produced evidence which seemed to show pretty conclusively that the strength of the acid in the pickling bath has a positive influence on blistering; but fish-scaling is a defect

[1] Treischel, THIS JOURNAL, **2**, 774.

distinctly different from blistering. It may be that the two defects are very similar insofar as their cause is concerned. In this series of experiments, the laboratory trials were all pickled in a strong hydrochloric acid solution (10 per cent) while those made in the factory were pickled in dilute sulphuric acid. There is not sufficient evidence here on which to base any conclusions of value but what there is would indicate that the pickling had little bearing on the subject.

Poor steel is a favorite excuse for many enamelers in assigning a reason for fish-scaling. It would seem that it ought not to be a very difficult to prove whether this is true or not. In this series of experiments, three grades of steel were used, Bessemer, open hearth and American ingot iron. The data shows that formula 12, one of the three which developed fish-scaling in the laboratory, shows the defect on all three kinds of steel. Here again, what little data was obtained would seem to indicate that the grade of the steel has little bearing on the subject.

One fact that is universally recognized is that fish-scaling is much more common on heavy gauge (20 to 16) than on light gauge (28 to 20) steel. This was recognized throughout the experiments, both in the laboratory and the factory. It is quite evident that this fact, with all that it signifies, must be considered in the solution of the problem.

Preparation, application and burning of the enamel are all fields capable of containing the main cause of the defect. One point in this connection was touched upon in these experiments. The enamels made in the laboratory were all ground dry, giving enamels with a much smaller percentage of fine material than is obtained in wet grinding. It is possible that further investigation of this point would show this to be one of the chief reasons for the difference in results obtained in the laboratory and factory, and reveal one of the chief cusaes of fish-scaling. Coarse grinding is quite universally recognized to give best results in ground coats.

Finally, while it is admitted that all the data here obtained is negative in character, still it is believed that not a great amount of additional data of this kind would be required to point to the proper solution of this problem.

It is the belief of the writer that fish-scaling will be found to be due, not to one single cause, but to a combination of contributory causes. The fish-scale seems likely to be a small chip of enamel forced off the steel by the expansion of gas under it. The gas bubbles are always present, whether fish-scaling occurs or not; but when the other conditions are properly combined, fish-scaling occurs. What are these other conditions?

NEW YORK STATE SCHOOL OF CLAY WORKING AND CERAMICS
ALFRED, NEW YORK

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

A LINING FOR GLASS POTS[1]

By S. R. Scholes

It is the purpose of the present paper to describe a process for manufacturing glass pots which renders them less corrodible by the molten glass and extends their useful life, at the same time improving the quality of the glass produced. This process is particularly applicable to pots used in the melting of heavy lead glass containing potash. It is characteristic of potash-lead glass, that while it is not a very good solvent for clay, nevertheless on account of its density and fluidity at the melting temperature it penetrates the interstices of the pot wall, causing the well known "honeycomb" effect. A further result of such action on the pot wall is that it loosens less soluble portions of the wall, usually consisting of grog particles that float into the glass where they appear as stones and cause much loss of production and rejection of otherwise well made ware.

In the attempt to remedy this condition, that is, to produce a pot resistant to the "honeycomb" action of potash-lead glass, it was readily recognized, in accord with the opinion of Seger and other authorities, that the physical rather than the chemical constitution of the pot wall is of greater importance. Porosity tests made by boiling a weighed piece of pot shell in water, cooling it in water, then wiping off the surplus water and re-weighing, showed that the usual pot wall, except portions that have been greatly overburned, has a porosity, expressed in terms of per cent of water absorbed, averaging 10 per cent. It is thus easy to see how a considerable penetration could be effected by melted glass.

The problem then was to reduce this porosity so as to present an impenetrable wall to the glass. It was considered best not to make the entire pot out of non-porous material for the reason that glass pots are subject to such great variations in temperature,

[1] Received February 27, 1920.

and the looser structure of the wall permits expansion and contraction with less danger of fracture. The attempt was made to develop a lining, carried upon a pot wall of the ordinary porous refractory type, which should protect the wall against the attack of the glass.

A refractory clay body having the general character of porcelain is recognized as the least porous that can well be produced. Such a body it was found after some experimentation could be formed from the ordinary glass pot batch by the introduction of feldspar to form a sintering bond between the clay particles producing the phenomenon generally referred to as vitrification. Test pieces made in this way showed less than 1 per cent porosity under the treatment described above. The fragments of such vitrified pieces showed a very small rate of attack by fused sodium carbonate, compared with pot shell.

A choice of suitable composition for the feldspar clay mixture depended entirely upon the temperature at which the pot was to be used. In the first large-scale experiment the mixture of 90 per cent pot batch and 10 per cent feldspar was fixed upon, since this formed a very dense body after burning at 1300° C, yet did not show over burning at that temperature.

The process of applying this lining to the glass pot was simple. The lining mixture, worked up into rolls in the usual manner, was placed along the bottom and sides of the pot, as the latter was built, forming a finger-course about $^1/_2$ inch thick up to the metal line and diminishing in thickness, leaving off about 8 inches higher. Because of the fact that the lining material did not differ materially in proportions of raw clay and inert material from the composition of the balance of the pot, no difficulty was experienced in drying the pot, and a homogeneous body was obtained at all times.

The results obtained in using such pots have been very good. Experience has shown that it is often necessary to reduce the proportion of feldspar as much as 5 per cent. After firing in the furnace the lining develops a very dense structure and formation of stones is reduced to a mimimum. Also, the attack on the pot wall is greatly retarded so that the useful life of the lined pot is from two to three times that of the ordinary pots, in potash-lead

glass. Moreover, although the lining itself may be entirely dissolved from a certain portion, notably the "knuckle" of the pot, it has by that time protected the wall until the latter has reached a stage of vitrification causing it to be very resistant to corrosion. The only difficulty experienced has been in the formation of cracks in the lining, due to the inability of such dense material to withstand the cooling shocks incident to charging with cold batch. These cracks, while not worse than those ordinarily forming in pots, permit the glass to penetrate into the less resistant pot wall and are really the cause of the final failure of the pots.

These lined pots are easier to handle than pots made entirely of porcelain material because, in the first place, the lining matures readily at the ordinary melting temperatures, and second, because of their more porous structure in the raw condition they may be brought up in the pot arch fully as rapidly as ordinary pots.

The above work was carried on under a fellowship established at Mellon Institute of Industrial Research, Pittsburgh, Pa., and the writer wishes to acknowledge the coöperation of the staff of the Mellon Institute and Mr. W. R. Irvin of the Laclede Christy Company under whose supervision the lined pots were first manufactured.

H. C. Fry Glass Company
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CERAMIC ABSTRACTS

General

The asbestos industry in 1919. O. Bowles. *Eng. Min. Jour.*, **109,** 224–5 (1920).—The following topics are briefly treated: Uses, market conditions, prices, domestic production, conditions in Canada, South Africa, Russia; problems of the producer. E. D. Elston.

Chrome in 1919. S. H. Dolbear. *Eng. Min. Jour.*, **109,** pp. 171–2 (1920).—The domestic industry is reviewed in a superficial manner and brief references are made to some of the foreign sources of chrome. E. D. Elston.

Chrome mining in Canada in 1919. R. Harvie. *Eng. Min. Jour.*, **109,** 172 (1920).—The production was limited to the Black Lake and Richmond districts of Quebec and approximates one-half of the production of 1918. E. D. Elston.

Colloidal clay in soap manufacture. F. E. Weston. *Brit. Clayworker*, **28,** 245–46 (1920).—Clay may be brought to such a high colloidal state that it closely resembles soap in its physical behavior and when incorporated with soap increases the lathering and detergent properties. probabiy due to the formation of a solid solution with the soap. After a certain maximum of alkali is added to soap it is coagulated and loses its lathering power, being similar to clay which is also coagulated by the addition of an excess of alkali. Physically clay and soap are very similar since their surface tensions are lower than that of water, their viscosities greater, they both possess emulsifying properties, both have power of absorbing dirt, grease, etc., and both have detergent properties. A comparison of the surface tension of various mixtures with water by the capillary method gave the following results:

	At 20° C gr. cm.	At 45° C gr. cm.	At 96° C gr. cm.
Water	0.07205	0.06825	0.06116
7.45 g. colloidal clay + 0.125 Na_2CO_3 + 250 cc. water	.07013	.06791	.06013
0.5 g. soap in a 100 cc. sol. of water	.02422	.02215	...
0.5 g. of mixt. (80 soap and 20 clay) in a 100 cc. sol. of water	.02200	.02062	...

A solution was prepared containing 0.125 gram sodium oleate in 100 cc. sol. of water. Portions were mixed with normal Na_2CO_3 solution, and after shaking the volume of lather (*a*) and of solution (*b*) were measured.

	10 cc. sodium oleate + 10 cc. N Na_2CO_3 soln.		10 cc. sodium oleate + 10 cc. N Na_2CO_3 sol.n. + 0.01 gr. colloid clay	
	a	*b*	*a*	*b*
1.....	16.0 cc.	18.0 cc.	19.0 cc.	15.2 cc.
2.....	16.0 cc.	17.8 cc.	20.7 cc.	14.8 cc.
3.....	16.3 cc.	17.2 cc.	21.6 cc.	14.9 cc.
4.....	17.0 cc.	17.0 cc.	21.6 cc.	14.9 cc.

Alkalies in face soap are harmful to the skin whereas clay in soap is not.
H. G. SCHURECHT.

Feldspar in 1919. J. V. LEWIS. *Eng. Min. Jour.*, **109,** 238–9 (1920). A reduction of 15 to 20% of the 1918 output is expected for 1919, due to existing conditions of labor, shipping, etc. The reduction occurred mainly in Pennsylvania, Maryland, California, and to a lesser extent in North Carolina. The 1919 Canadian production is reported to have suffered a considerable decrease.
E. D. ELSTON.

Mica in 1919. J. V. LEWIS. *Eng. Min. Jour.*, **109,** 237–8 (1920).—Production, imports and exports, and prices are briefly considered and new sources of possible commercial importance are noted as follows: A new biotite deposit in North Carolina, deposits in Guatemala, and several occurrences in Siberia.
E. D. ELSTON.

Silica, an aid in the determination of. S. R. SCHOLES. *Chemist Analyst,* No. **29,** pp. 22–23.—In the analysis of silicates, where silica is separated by evaporation with hydrochloric acid, it is not easy to detect the last small particles of silica adhering to the evaporating dish when the evaporated mass is taken up with water and filtered. Methyl orange is very helpful in this operation. Not only is this a suitable indicator to make certain the acidity of the liquid as it evaporates, but as the gelatinous silica separates it becomes strongly colored by the methyl orange. The silica retains its orange dye quite strongly in the subsequent washing. Each particle of silica is readily detected on the evaporating dish, and the analyst may be sure when all the silica has been brought upon the filter. One may thus avoid the necessity of drying the dish to ascertain whether or not silica has been left behind.
A. J. LAMBERT.

Talc and soapstone in 1919. R. B. LADOO. *Eng. Min. Jour.* **109,** 235–7 (1920).—Brief statements concerning the talc industry include the following topics: Uses of talc as a substitute for English clay; as a substitute for graphite, and as a filler; reorganization of the industry; development of domestic sources; prices, production and imports; foreign situation.
E. D. ELSTON.

PATENTS

Heat-insulating material and process of making it. W. H. WINKLEY. U. S. 1,332,370, March 2, 1920. This is a composition very similar to that disclosed in U. S. 1,332,348. However, because of the deliquescence of caustic soda, a mixture of sodium carbonate in the form of soda ash and hydrated lime is substituted therefor. The proportions used are: Infusorial earth 85 parts, gelatinized starch 10 parts, soda ash 5 parts, and hydrated lime 2 parts.

Heat-insulating material and process of making it. R. B. MACDONALD. U. S. 1,332,348, March 2, 1920. A heat-insulating, heat-resisting material is made of 100 parts infusorial or diatomaceous earth, 3 parts gelatinized starch, added to lend sufficient coherence for molding, and 1 part sodium or potassium hydroxide. This material may be used as a mortar or as a paste to be applied to steam boilers or it may be made into blocks and dried at 300° F. It is said to be able to withstand 3000° F.

Kiln. R. C. PURDY. U. S. 1,332,471, March 2, 1920. This is a round downdraft kiln of a modified Lawton type. The hot gases divide at the rear of the fire box, a part rising vertically through the bags as in an ordinary downdraft kiln, and a part passing through radial flues beneath the floor to a center well or bag which rises within the kiln chamber a distance a little less than half the height of the crown above the floor. After passing through the ware the gases pass through aperatures into other radial flues beneath the floor and outwardly into individual stacks located within the peripheral wall of the kiln. Improvements have been made in the structure and arrangement of flues beneath the floor.

Tunnel-kiln. G. W. BOOTH. U. S. 1,333,099, March 9, 1920. Atmospheric air enters spaces within the walls and crown of the kiln at the end of the cooling zone, passing through these spaces along the length of the kiln at the end of the cooling zone, passing through these spaces along the length of the kiln and down through vertically disposed iron pipes which line the walls of the preheating zone. Ware entering the kiln is thus preheated without coming into contact with products of combustion.

Tunnel kiln, continuous. C. J. KIRK. U. S. 1,332,501, March 2, 1920. This is a twin tunnel muffle kiln, the ware traveling in opposite directions in the two tunnels, thereby effecting a mutual cooling and preheating. The longitudinal partition wall is provided with staggered openings at top and bottom to permit of circulation of air between the two tunnels.

G. E. MIDDLETON.

Refractories

Muffles. *Tonind, Zeit.*, **44**, 168–9 (1920).—The requirements of a muffle are (1) resistance to temp. change, (2) mechanical strength and (3) good conductivity. About 2 parts of grog are used with 1 part of bond clay. For small muffles the size of grain is about 1–2 mm. Sawdust is often added to the body to make it lighter in weight and more resistant to sudden temp. change. Muffles should not be burned too high as this facilitates cracking.

H. G. SCHURECHT.

Graphite in Quebec, Canada. H. P. H. BRUMELL. *Eng. Min. Jour.*, **109**, 548–550 (1920).—Graphite is of widespread occurrence in Quebec, especially in Argenteuil, Labelle, Wright and Pontiac counties where in the Grenville or upper part of the Laurentian series of rocks it occurs as disseminations, in masses and in veins, the first named type of occurrence being the most important.

The Quebec and Alabama graphite may be briefly compared as follows: (1) The Buckingham ore is Archaean in age while the Alabama material is Carboniferous. (2) Genetically, Buckingham graphite is inorganic or elemental. The Alabama graphite is organic and due to alteration of coaly or carbonaceous material contained in the sandstones prior to metamorphism. (3) In Quebec near the eruptives there is an enrichment of graphite while in the Alabama deposits an increase in muscovite occurs without appreciable change in the graphite content. (4) Alabama ore consists almost entirely of soft weathered ore; the Buckingham material is usually tough and hard. (5) Mineralogically they are similar affording "flake graphite." The gangue in the Alabama ore, however, consists almost entirely of very friable quartz with a small amount of sillimanite (?), occasionally mica (either biotite or muscovite), cyanite and tourmaline. The Buckingham material is accompanied by some quartz together with such common minerals as orthoclase, pyroxene, hornblende, sillimanite and occasionally mica (usually biotite), zircon, tourmaline, chondrodite and pyrite. (6) Buckingham graphite is a coarser flake with higher specific gravity than that of Alabama and is in greater favor with crucible manufacturers. The Quebec graphite has a higher specific gravity than Ceylon graphite and in its heat-resisting qualities is practically the equal of the Ceylon material. Methods of concentration are considered and tables are included which show: Specific gravity and refractory values of both domestic and foreign graphite; analyses of graphite from various North American districts and from Ceylon; grade of Buckingham deposits; screen tests on Quebec and Alabama materials. E. D. ELSTON.

Graphite industry during 1919. B. L. MILLER. *Eng. Min. Jour.*, **109**, 226–227 (1920).—The article is a somewhat generalized review of the industry and deals briefly with the following phases: War demand for graphite crucibles, the development in Alabama, graphite imports limited, preference

of Ceylon material for crucible manufacture, exclusion of graphite in War-Minerals Relief Bill, prices, 1919 production in the United States, Ceylon graphite industry in 1919. E. D. ELSTON.

Magnesite in 1919. W. C. PHALEN. *Eng. Min. Jour.*, **109,** 217–9 (1920).—A general review of the magnesite industry is given. Among the topics briefly treated are the following: Stocks on hand at end of the war, unsettled domestic industry in 1919, industry in the west, effect of car shortage on production, Canadian magnesite industry, tariff legislation, uses of magnesite and quality of the domestic product. E. D. ELSTON.

Graphite industry in Alabama in 1919. W. F. PROUTY. *Eng. Min. Jour.* **109,** 228 (1920).—Crippling of the industry due to removal of import restrictions on graphite is briefly discussed. E. D. ELSTON.

Glass

Bohemian glass industry. *Chem. Met. Eng.*, **22,** 464 (1920).—The well known glass manufacturing district of Jablonec (Gablonz), in the Republic of Czechoslovakia, alone exported from February 1 to October 31, 1919, products valued at 17,000,000 Czechoslovak crowns, mostly to the United States, France and Italy. Previous to the war, of the 202 glass furnaces in the Austro-Hungarian empire, 162 were in the Czechoslovak domain. Of the total production for 1913, valued at 117,400,000 crowns (the normal value of the Austro-Hungarian crown was 20 cents—United States currency), 105,500,000 crown represented the Czech and Slovak products.

A. J. LAMBERT.

Electrical conductivity of soda-lime glasses. R. AMBRONN. *Ann. der Phys.* (4) **58,** 139–64, 14/2 (1919), 20/8 (1918); *Chem. Zent. Bl.* No. **5,** Bd. 11, p. 176 (1920).—Previous investigations of conductance in glasses were accompanied with many difficulties because ordinary glasses contain usually from 5 to 8 components and it was impossible to determine quantitatively the relation of conductivity to chemical composition. By utilizing 13 special glasses made by Schott, which consist of only Na_2O, CaO and SiO_2, the investigator has established the relation of the electrical conductivity of these glasses with their content of Na_2O and CaO to temperature. The relation of the conductivity to temperature is expressed by a simple exponential function with the reciprocal of the absolute temperature as exponent. A glass containing only Na_2O, CaO and SiO_2 shows values differing from zero only when its content of Na and Ca atoms together comprise at least 11 atoms to each 100 atoms of the glass substance. It is noteworthy that we must not consider Na_2 but an Na with a Ca atom. WM. M. CLARK.

Glass and glass making. ESTHER SINGLETON. *The Mentor*, **7,** No. 5.—Like most of the arts, glass making originated with the Egyptians and the

Phoenicians, and was carried by them to the isles of Cyprus and Rhodes, thence to Rome, and from Rome throughout western Europe. In Egypt its use was chiefly decorative, and among archeological remains are glass beads, vases of glass for cosmetics, unguents, and kohl, small pitchers, scarabei or sacred beetles, many of which antedate the Christian era by two thousand years. The Egyptians favored blue in their glassware, of all shades from dark to the famous "Nile blue," mustard and pale buff, pale green, and red in imitation of jasper. The Phoenicians, on the contrary, produced a pure white glass for use in vases, and an opaque glass for beads. Historians agree that glass production was not indigenous to Greece, for it is not until the fifth century, B. C., that we find any mention of it by their writers. Remains are still extant, taken from the Cyprian and Rhodian islands. They are chiefly small bottles, colorless, or of pastel shades, pale green, rose or buff. By the Augustan era the Romans had converted the art of glass making into an industry, and factories for glass manufacturing had sprung up all over the Empire. These factories turned out every conceivable utility and employed every color but ruby, their glass varying from opaque to milky white, mottled, variegated, and opalescent, and extended in its use to include not only bottles but ornaments of many kinds, dice, tiny balls to cool their hands, and once, to please an emperor's fancy, an entire banquet of glass viands. Byzantine and Venetian artists inherited the Roman science, and were welcomed guests in all the courts of Europe. It was a Byzantine artist who constructed the famous Holy Grail, and another who made the not less important "Hedwig Glasses," heavy dark-colored tumblers, cut on a wheel and with figures in high relief. Enameled glass, which was popular throughout the Middle Ages, was particularly the product of the Arabian and Saracen, who had adopted it from the Persians dwelling in Damascus and Aleppo. Over its texture of dull gold gleamed the red, blue, white and green enamel. After Tamerlane captured Damascus, the art was carried to Samarcand where Damascan artists, although in captivity, still continued their craft. Venice was famed for her enameled glass as late as the sixteenth century, when she abandoned enamel for the beauty of colorless, transparent, fairy forms. Modern European countries with their heritage of Roman, Byzantine, Saracenic, and Venetian skill, have accepted and adopted according to their national characteristics. Thus France, while opening her doors to the Venetians, turned their art to the creation of stained glass for her cathedrals. Dutch and Belgians preferred to excel in exquisite engraving of bottles and glasses. German glass blowers strove for and achieved unique forms, and attained also those blue-green shades distinctive of the Rhenish bottles. The glass of Bohemia had a brief popularity during the eighteenth century, then was pushed aside to give way to the English flint glass. J. VAN DE WATER.

Glass and some of its properties. SIR HERBERT JACKSON. *J. Royal Soc. Arts.*, **68**, 134–46 (1920).—Glass is not a solid. Long straight pieces of glass rod or tubing if left unsupported will slowly bend and after some years

will become definitely bowed. Different glasses show varying degrees of bowing, but all change somewhat. Plasticity of a glass is of the greatest importance for sealing-in work with metal wires and also in resistance to sudden temp. changes. Two glasses of the same coeff. of expansion may vary greatly in plasticity. In the case of soft metals like copper and platinum the glass in setting seems able to pull and deform the metal wires so that no great permanent strain is left in the glass, while with hard metals like iron and tungsten such metal flowage is not possible and the resultant strain will crack the glass unless the glass possesses marked plasticity. Glass seems to be a truly vitreous and not a crystalline body. Neither etching nor a tearing of the surface by glue dried thereon reveals any definite evidence of a crystalline structure in a clear vitreous glass. Phosphorescence varies greatly in glasses and is particularly strong in glass for X-ray bulbs. B_2O_3 and Al_2O_3 are well known as retarders of crystallization, but TiO_2 is even more striking in its action as a vitrifying agent. Glasses with Na only as the alkali devitrify much more readily than similar glass with K or mixed alkali. Most opal glasses owe their milkiness to globules in which are no evidences of crystallization. Opal glasses produced by phosphates generally "strike" opal at higher temperatures than those made with fluorides, the compounds formed by the fluorides being more soluble than in the case of the phosphates. In general fluoride opals are better for working than phosphate opals, especially in the denser opals. For merely opalescent glasses phosphates give good results, but with greater concentrations of the opal-forming substance there is a tendency to crystallize. Colored glasses may be divided into two main groups (1) with the coloring matter diffused in small particles, which may be likened to colloidal solutions and (2) with the coloring matter in a state resembling that of solution. There is, however, a gradual gradation through both groups. Typical of those in class (1) are glasses colored by gold, copper and selenium. Quick chilling will with each of these materials, yield a clear colorless glass and the greater the concentration of coloring matter the quicker the chilling necessary to prevent color. On reheating they "strike" colors just as opals do. Gold glasses are discussed at length. Glasses colored or decolorized by manganese may be considered as intermediate between groups (1) and (2). Of group (2) glasses colored by nickel and cobalt may be considered typical. Varying proportions and kind of alkali influence such colors markedly. Used in equivalent amounts the coloring in the presence of potash is strongest, sodium next and lithium least. With cobalt the influence is less marked than with nickel.

C. H. KERR.

Glass grinding and polishing. JAMES WEIR FRENCH. *Sci. Am. Supp.*, **83**, 308–310 (1917).—When a metal surface is polished, small scratches and pits become covered over with a continuous surface flow layer, and if this surface layer is removed by etching these scratches are exposed. On etching a polished glass surface, fine scratches appear, and it has been wrongly assumed

that glass behaves like metals. In the workshop two kinds of scratches are recognized; one exhibiting irregular fractures is called a "cut," and the other, having clean, well-defined edges, is called a "sleek." The result of this investigation shows that the surface layer of polished glass has somewhat different properties than the original glass. A cut is a scratch in the original glass and a sleek a scratch in the modified material or surface layer. It is these scratches in the surface layer that reappear on etching. An optical glass surface is produced as follows: When the polishing tool, which frequently consists of a flat layer of pitch on the face of a metal plate, is rubbed on the glass surface, the portion of glass in immediate contact becomes liquefied to a depth of about $^1/_{4000}$th to $^1/_{5000}$th inch, and the molecules rearrange themselves uniformly under surface tension. The polishing medium subdivides, breaks up, and removes the surface layer, thus exposing the underlying material. The process repeats itself, and a perfect surface is obtained only by the removal of material beyond the bottom of the hollows produced in the glass during the earlier smoothing process. Although the action of a soft cloth polisher is fundamentally the same as that of a pitch polisher, the surface of the latter being flat and comparatively unyielding, touches only the top of the ridges and gradually liquefies successive horizontal layers, while the cloth polisher comes in contact with the surface of the hollows and the glass surface has a tendency to retain its original shape. A perfect optical surface cannot be obtained with a cloth polisher. A surface that is not completely polished exhibits what is technically known as "greyness" when the polisher is a pitch one. The greyness is caused by scattered light from the hollows. A cloth polisher will mask this greyness but the pits still remain and the glass is optically imperfect. A block of crown glass having one polished and one smoothed face was heated to a temperature which appears to have been below the softening point of the main body of glass and just above that of the surface layer. The smoothed unpolished surface remained unaltered, whereas the polished surface exhibited a network of grooves, due apparently to softening and contraction of the surface layer, in which there must evidently have been a considerable tension. By measuring the depth of these grooves the thickness of the modified surface layer is obtained. J. L. CRAWFORD.

Glass manufacture and the glass sand industry of Pennsylvania. C. R. FETTKE. Topographic and Geologic Survey of Pa., *Rept.* No. **12**, (1919).—The first eleven chapters deal with the technical side of glass manufacture. Among the topics considered at length may be mentioned the following: Definition, composition and classification of glass; chemical and physical properties of glass; raw materials; preparation of the batch; consideration of fuel and of pots and furnaces used; processes of fusion, annealing and other processes used in the working of glass. Following these topics is a chapter on the statistics of the glass sand industry of Pennsylvania and several chapters dealing with the glass sands of that state. The distribution of glass sands is considered according to geological formations and also with respect to coun-

ties. Two formations furnish all the glass sand produced in Pennsylvania—in the central part of the state the Oriskany is the horizon while the Pottsville furnishes material in the west. Of these two formations the Oriskany is the most important. Screen tests, sections and analyses are given.

E. D. ELSTON.

Glass manufacture at the end of the war. MORRIS W. TRAVERS. *Jour. Soc. Chem. Ind.*, **38**, 388–391.—The results of the war work show that research must be made into the nature of glass, and experimental methods for this must be developed. The difficulties of this research are enhanced by the nature of technical glass which often, if not usually, represents unstable systems, and it is, therefore, unusually difficult to find any close relationship between the composition and properties. Another difficulty which will confront future investigators, as it did those who undertook the research at the beginning of the war, is the paucity of literature on the subject and the unreliability of the literature which does exist. A reasonably perfect resistance glass for chemical glassware has yet to be discovered, and also a furnace capable of working at temperatures high enough to produce lamp-working glass. This glass must be soft and have a low melting point, but it will "plain" only when very strongly heated in the furnace. The chemistry and physics of founding and plaining of glass need further development. A physical constant in lieu of a melting point (perhaps the point of cohesion of two pieces of glass in optical contact) should be determined; as also the viscosity of glasses, information about which would be of use to manufacturers who employ mechanical methods of glass blowing. There is considerable scope for investigations of the materials used in the glass trade. The influence of accidentally-introduced constituents should be known and the possibilities of substituting less expensive materials for those generally used. Methods of handling and treating materials in the glass trade are exceptionally backward and one of the future efforts of research may well be concerned with developing modern methods of manufacture and the utilizing modern machinery in the mechanical parts of glass making. Efficiency methods should be introduced into the plants. Furnace problems, especially those which concern the manufacture and treatment of refractories, are of the utmost importance and the inefficient old-fashioned round furnace should be replaced. England is behind America in the development of mechanical methods of glass making, and in the investigation of the methods already developed. Due to the war, the demand for tubing has increased enormously and the methods of working varied widely among the different glass houses. Statistical information as to these methods would be useful in determining the best processes of gathering, marvering, reheating, etc. Tubes over one inch in diameter should be annealed before issue. Results of the work already done only prove that further knowledge of annealing is necessary. English manufacturers, in order to keep their continental trade, should not fail to return to hand working of flint glass for which, before the war, they were justly noted.

J. VAN DE WATER.

Glass sands in South Africa. DR. PERCY A. WAGNER. *Mining Magazine*, **21**, 180–183 (1919).—Research by Wagner upon South African glass sands has been limited to occurrences which may be drawn upon in the near future. Despite lack of investigation, enough is known to warrant the statement that in the Union there are vast quantities of sands suitable for the manufacture of all kinds of glassware except the very finest grades. One occurrence, near Piennaarspoort, in the Magaliesberg, Transvaal, has been used for glass bottles. The sand is pale yellowish white and contains 0.068% heavy minerals. The maximum thickness exposed in the pit is 2 feet 6 inches. It occurs beneath dark gray sandy loam and is composed almost entirely of quartz grains most of which are coated with thin films of ferruginous clayey matter. Additional characteristics are as follows: Concentrate contains 28% magnetic particles; minerals include zircon, rutile, anatase, cyanite, limonite and ilmenite showing alteration to leucoxene; sand is poorly graded and in this respect is inferior to most European and American glass sands. The best material is of the following chemical composition:

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss on ignition
Unwashed sand.....	98.98	0.57	0.10	None	Trace	0.31
Washed sand.....	99.46	..	0.08	...	...	0.20

Extensive deposits of sand suitable for glass making are found in the Moot Valley, especially on the farm Zandfontein, where there is a belt some hundreds of yards wide and at least 2 miles long. While this sand is better graded than the Piennaarspoort material, still it is inferior to the best European and American glass sands. Its chemical and mineralogical composition, however, prove it to be well suited to the manufacture of white bottles and the better grade white glassware, With washing and screening it would probably be good for plate glass. Numerous other occurrences are described in the article and grade analyses and chemical analyses are given. The location and possible uses of the materials are briefly treated. E. D. ELSTON.

Influence of glass on contents of bottles. *Ztschr. f. ges. Kohlensure Ind.* **25**, 657–58, 673–74; *Chem. Zentbl. Nr.* **4**, Bd. 11, 130 (1920).—Discusses the composition and properties which glass must possess in order to be satisfactory as a container for beverages of all kinds, for example, fruit juices, cider, mineral waters, cordials, alcoholic beverages, in order that the contents shall not be affected in quality or composition. A satisfactory glass contains silica as the main constituent and at least two other metallic oxides, for instance, alkali and lime. The lime content must not be too great, and if it exceeds 20% the glass will be attacked by organic acids and alcohol so that the quality of the beverages from long exposure is deteriorated. If the glass is very finely powdered and exposed to dil. HCl 24 hours it should not lose more than 3% by weight. The suitability of glass can be determined by exposing to vapors of conc. HCl 24 hours when if it shows a white film of chlorides by transmitted light in a room free from dust and NH_3 vapor it is

not suitable for drinking glasses and bottles. A more sensitive method was worked out by Mylius who digests glass 24 hours in an ethereal solution of iodeosin, $C_{20}N_8J_4O_5$. The alkali-eosin formed is insoluble in ether but dissolves in water forming a pinkish color. By comparing with iodeosin alkali sols. of known strength, the degree of attack on the glass surfaces can be quantitatively determined. WM. M. CLARK.

Standardization of forms of chemical glassware. DR. H. THIENE. Production Engineer of Schott & Gen. Glass Works. *Z. f. ang. Chem. Nr.* **6**, 33 Jahrg, 18 (1920).—Detailed discussion of sizes, dimensions and capacity of Jena chemical ware. WM. M. CLARK.

PATENTS

Blowpipe-operating mechanism for glass-forming apparatus. A. KADOW. U. S. 1,331,772, Feb. 24, 1920. A rotary support carries in circumferential arrangement a number of sets of glass-forming mechanisms, each set comprising a blow-pipe or spindle, a gathering device which withdraws glass from the furnace and delivers it to the spindle, and a finishing mold. The spindle with a blank thereupon is revolved on its longitudinal axis and air blown into the blank. The spindle is then oscillated, the blank then placed in a finishing mold and rotated therein by renewed revolution of the spindle on its longitudinal axis. This renewed revolution of the spindle is more rapid than the first, and in consequence of this rapid movement higher air pressure can be used. Greater uniformity in wall thickness can thus be attained and this is of particular importance in blowing electric light bulbs.

Charging Glass-molds, means for. J. F. RULE. U. S. 1,331,528, Feb. 24 1920. This machine is very similar to the one shown in U. S. 1,331,512, above. Here, however, there are two arms carrying gob-forming cups which are alternatively fed from the same furnace, each arm then carrying its charge to a rotary mold table adjacent to it.

Color-filter for artificial light, glass composition for. M. LUCKIESH and D. A. DEWEY. U. S. 1,331,937, Feb. 24, 1920. This is a glass adapted to be used in connection with artificial light for the purpose of producing an effect similar to that of daylight. The batch formula is as follows: Sand, 1500, soda 535, lime 160, niter 50, arsenic 5, manganese dioxide 3, cupric oxide 5.66, black oxide of cobalt 0.26 pound. This results in a glass which is bluish in color but which has a slight greenish tinge. A very close approximation to various kinds of daylight may be obtained by its use, depending upon the thickness of the glass. Where it is necessary to decrease the heat effect caused by a large proportion of the green element the proportion of black oxide of cobalt may be decreased. When it is desired to approximate skylight a purple glaze having the following batch formula may be applied to the surface of the glass: Vitrifiable carmene (No. 45) 50, vitrifiable blue (No. 245) 2.5, vitrifiable flux (No. 10) 30 grams.

Glass-drawing pot. C. DAY. U. S. 1,333,903, March 16, 1920. This is a double pot construction designed so that while one pot is in a drawing position the other is draining. The pots are mounted, one on each arm of a V, the angle between the arms being 90°. Rotation is about an axis bisecting the angle of the V. When one pot is horizontal and being drawn from, the other is vertical and exposed to the heat of a furnace which melts the residual glass and causes draining. By rotating the V-shaped support about the bisecting axis the position of the pots is reversed.

Glass-feeding apparatus. K. E. PEILER. U. S. 1,332,405, March 2, 1920. Charges of glass are delivered from the delivery spout of a trough by the action of a displacer. This latter is an inverted truncated pyramid of refractory material which moves downwardly and forwardly through the glass during the feeding stroke and then upwardly and backwardly. This motion moves the glass forward in waves or surges which flow over the spout and drop into receptacles positioned to receive them.

Glass-flattening apparatus. G. H. HAHM. U. S. 1,331,916, February 24, 1920. Halves of the usual glass cylinders suspended by one of the longitudinal edges are slowly carried through a heating chamber in which they soften and gradually straighten. When approximately straight they are held against a flat vertical slab and flattened by being rubbed by a succession of horizontal bars carried by two endless chains. Thereafter they are passed into a cooling chamber.

Glass-molding machine. S. E. WINDER and H. C. DAUBENSPECK. U. S. 1,331,792, Feb. 24, 1920. A series of molds are mounted upon a rotary table. Glass is automatically fed to the molds at one point, at another a plunger descends and presses the article to shape (glass tumblers are instanced) and at another the molded articles are ejected by an upward movement of the mold bottom.

Glass-working machine. F. L. O. WADSWORTH. U. S. 1,333,143, March 9, 1920. This machine is one which makes glass articles by a combined pressing and blowing operation. Successive charges are cut from a flowing stream of glass and fed to a blank or parison mold in which a press plunger operates to mold the blank. The articles is then blown to final form in another mold.

Lens-forming process. H. W. HILL. U. S. 1,332,724, March 2, 1920. The stock is heated to a plastic condition and puddled to eliminate bubbles, striae and similar defects. It is then pressed into form while still plastic and the formed lenses annealed before they have entirely cooled from the initial heating.

Lens-molding machine. H. W. HILL. U. S. 1,332,725, March 2, 1920. This is a machine designed to carry out the process of U. S. 1,332,724 and comprises a rotary heating and puddling table, a heated transfer mechanism, a peripheral rotary mold and an annealing chamber.

Transferring molten glass to molds, means for. L. D. SOUBIER. U. S. 1,331,536, Feb. 24, 1920. This machine is similar to the one shown in U. S. 1,331,511, below; instead, however, of having an oscillating chute it is provided with a plurality of such chutes which rotate continuously about a common axis and in synchronism with the mold table.

Transferring glass to molds, apparatus for. R. LA FRANCE. U. S. 1,331,511, Feb. 24, 1920. Gobs of molten glass are fed to an oscillating chute, which swings in synchronism with a continuously rotating mold table during the time the gob is being fed to a moving mold.

Shear mechanism for glass-working machines. H. A. GENEST. U. S. 1,331,847, Feb. 24, 1920. When the glass-shaping machine to which the charges or gathers cut from the supply by the shears are fed is stopped for any reason, such as for repairs or adjustment, it is desirable that the flow of glass continue so that it will not "freeze" around the outlet. It is, however, desirable that the shear mechanism be thrown out of operation at this time. The mechanism of this invention enables the shear blades to be rendered inoperative and again put in operation in proper synchronism with the feeding means.

Sheet-glass drawing apparatus. B. G. BEALOR. U. S. 1,331,796, February 24, 1920. In drawing sheet-glass the sheet has a tendency to narrow as the drawing proceeds. According to this invention two fluid-cooled blocks are at the glass level in the drawing well and by cooling both edges of the sheet obviate the difficulty mentioned above.

Transferring charges of molten glass, apparatus for. J. M. LENTS. U. S. 1,331,512, Feb. 24, 1920. Molten glass is fed to a cup supported by a swinging arm. This arm swings over an adjacent mold on a rotary mold table, deposits a gob therein, swings back for another charge and then over a mold on an adjoining mold table. Thus one gob-forming and transfer mechanism feeds two mold machines. G. E. MIDDLETON.

Enamels

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Enamel for enameling articles of sheet or cast metal. C. MUSIOL. U. S. 1,332,058, Feb. 24, 1920. This is an enamel free of boron, lead, or arsenic compounds. The batch is made of saltpeter, soda, quartz, feldspar, kaolin fluorspar, sodium silico-fluoride cryolite, chiolite, antimony oxide, leuconine, magnesia, clay, tin oxide and appropriate coloring oxides, all in varying proportions. G. E. MIDDLETON.

White Ware and Porcelain

Cleaning stoneware clays. *Brit. Clayworker,* **28,** 260 (1920).—Attention is called to the fact that inferior stoneware is being produced in England owing to the fact that it is impractical to clean the clays properly. The injurious portions of clay are usually the coarse grains. If these were ground and added to the body in the 100-mesh size no ill effects would result but this would be too costly. If the clay contains large nodules of pyrites, these may be picked out by hand or with an electric magnet; but these methods are unsatisfactory in that they do not remove the finer material. A pug mill with a perforated barrel may be used to separate coarse stones but this does not remove the finer material. A blundger or wash mill may be used but the great objection is the cost in separating water from clay. If sulphuric acid is used to neutralize the soda, this tends to coarsen the clay and deprive it of its "silky" texture. Settling tanks are too slow. Filter presses are troublesome and costly. Evaporating tanks are costly and unpleasant. The electro-osmose process is too costly. None of the above mentioned methods are as cheap as can be desired, and there is a scope for ingenuity in this direction.

H. G. SCHURECHT.

Electric heaters made of ceramic materials. O. SCHNEIDER. *Keram. Rundschau,* **28,** 99–100 (1920).—Owing to a shortage of metals in Germany during the war, porcelain and majolica have been used successfully as a substitute for metals in the construction of electric stoves. The advantages of ceramic materials over metals are as follows: (1) They are good insulators, (2) they are easily cleaned and not effected by heat, (3) they make better reflectors of heat than metals since they do not absorb the heat very much but reflect it. Electric heaters are healthier than furnace or gas heaters, since they do not change the humidity of the air. Special stoves for heating and cooking are described. H. G. SCHURECHT.

German pottery factories, the recent visit to some. J. BURTON. *Pottery Gaz.,* **45,** 357–360 (1920).—Representatives of the British Manufacturers' Federation in visiting potteries in the occupied areas of Germany studying their manufacturing methods. German potters pay great attention to the quality of their saggers. All grog is carefully graded and screened in rotary screens. Saggers were made by hand, by hydraulic presses and in some cases round saggers were jiggered. In grinding pottery bodies recorders are placed on the mills to indicate the number of revolutions, thus reproducing homogeneous results. In German hard floor tile bodies, feldspar is always added to the body. Flint at the Bonn factory was calcined in special calcining kilns. The preparation of clay dust for tile was usually done in double-edge runners. Hand operated and hydraulic presses were used for tile and in the latter case the upper die was electrically heated, doing away with the use of grease for the lubrication of this die. Corrugated or perforated drying boards were used. Plaster moulds used for casting were always dried completely assembled and never with the respective parts separate. H. G. SCHURECHT.

Insulators, the destruction of high tension. E. O. MEYER. *Keram. Runds.* **28,** 1–2, 11–12 (1920).—In three years' service it was found that out of 977 insulators, 265 were cracked when used on a line in which the voltage amounted from 10–65 K. V. The fact that many insulators on low voltage line (10 K. V.) also show cracks and that many insulators which have been in use 20 years or more showed no cracks would indicate that high voltage and long service are not the causes of failure. It was thought that the pulling of wires during storms might cause the cracking but it was found that this only amounted to 600 kgs., whereas the insulators will stand 2500 kgs., also, cracks formed from pulling of wire are not identical with those observed in the insulators. Two types of insulators were used, one with shoulders (A) and another with no shoulders (B). In model A cracks were abundant; but in model B practically no cracks were found after having been in service. Insulators with sharp corners also showed more cracks than those with rounded corners. Those insulators which show a coarse grained fracture showed less cracks than those with fine-grained fractures. Temp. changes may vary from —20° C in winter to 50° C in summer with sudden chilling to 10° C during a rain. To test the effect of sudden cooling on insulators they were held at 80° C for 10 hours and then cooled to 10° C and then were again heated to 45° C and cooled to 15° C with rain. After one minute distinct cracking was heard and upon examination cracks similar to those found in insulators that had been in service were noticed. Further experimenting showed that the cracks were not due to the effect of temp. changes on the porcelain but to the cement which has three times the coeff. of expansion of the porcelain, which indirectly caused the cracking. It was found that in some cases the cement was not applied evenly one side being 2–3 mm. thicker than the other and in these cases the cracks occurred on the thick side. For the 65 K. V. insulators a thin cement layer of not over 2 mm. should be used on the bottom surface, 3 mm. on the cylindrical portion and not more than 4.5 mm. in the grooved portion. With 45 K. V. insulators the porcelain parts should be made true to dimension so that the cement layer will be uniform and 1.5–2.5 mm. thick.

H. G. SCHURECHT.

Metal technic and ceramics. E. HEINECKE. *Sprechsaal,* **58,** 65–6 (1920). —In 1880 a new decoration process was used which at that time proved very popular but at the present time this type of decoration has gone out of style. Upon the body to be decorated the ornament is put with a gold layer which is burned fast in a muffle kiln. The design appears as a dull unpolished layer of gold. The ware is then put into a copper bath where a thick layer of copper is deposited on the gold. The ware is then engraved and decorated by engravers. After engraving the vessel is put into gold bath and is thereby plated and the ware is then ready for market. Chinese ware is now appearing on the market having beautiful metallic decorations which may have been produced by a similar manner, although the exact method seems to be a secret.

H. G. SCHURECHT.

Pottery classes at Camberwell. STAFF ARTICLE. *Pottery Gaz.*, **45**, 354–355 (1920).—In day and evening classes the preparation of bodies, throwing, turning, modelling and mould-making, slip making and casting, glazing, drying and firing, and overglaze and underglaze decoration are taught. It is the object of the school to help the manufacturing potter in modelling aud designing wares and in producing wares that shall be related to current household furnishings. H. G. SCHURECHT.

Stoneware floor tile. E. TUSCHHOFF. *Keram. Runds.*, **28**, 69–70, 79–80 (1920).—White burning, tile must be burned to high temperature making them expensive. A stoneware clay vitrifying at cone 7–8 when used in the place of white clay produces a much cheaper tile although the color is gray instead of white. The following composition is suggested: 45% clay, 42% flint, 12.5% spar and 0.5% magnesite. H. G. SCHURECHT.

PATENTS

Hollow earthenware parts, method and apparatus for making. C. H. MUCKENHIRN. U. S. 1,332,514, March 2, 1920. In making hollow earthenware such as sanitary ware, a slab of clay is usually laid inside of a mold and pressed by hand to fit the mold, the presser beginning at the bottom and central part of the mold and gradually working outward and upward to assure escape of air. A machine is provided by this invention for carrying out the above-described process with the difference, however, that the slab of clay is applied over a core shaped to conform to the inner face of the article to be molded. A series of rotatable drums having concave pressing surfaces on their faces are arranged in line and operate successively upon the clay slab which passes beneath them mounted upon its core and carried by a conveyor. The first drum presses only the center and bottom of the hollow vessel, the next only those portions nearer the walls, and so on, the last one giving a finishing pressure to the entire surface. This machine is said to be especially well adapted to the pressing of sanitary ware which is made of relatively large pieces that are in turn built up of numerous small parts joined in a whole. The accurate character of the parts produced mechanically makes possible the use of slip in assembling the parts, avoiding the necessity for the soft clay roll joint.

Truck superstruction for sanitary ware. G. BRAIN. U. S. 1,333,381, March 9, 1920. The truck is designed for use in a Dressler tunnel kiln. The ware-supporting superstructure comprises two stories, the upper being substantially enclosed and designed to carry delicate goods and the lower being much more open and intended to carry goods not injured by more intense radiation from the walls of the kiln.

Support for tableware during firing. G. BRAIN. U. S. 1,333,380, March 9, 1920.—These supports are designed for use in muffle kilns. They com-

prise a triangular base plate having columns rising from each apex and on the inner sides of these columns are upwardly disposed recesses designed to hold pegs upon which the ware to be fired is supported. These supports may be superposed. G. E. MIDDLETON.

Brick and Tile

Red brick manufacture, important factors in. R. W. JONES. *Eng. Min. Jour.*, **109**, 490–491 (1920).—That failure in the manufacture of brick may in many cases be attributed to lack of proper geological examination of the prospect, together with lack of thorough chemical and physical examination of many samples of the raw material, is attested to by this brief article which cites examples of failures and states their ultimate cause. E. D. ELSTON.

Standard brick and tile in France. *Brit. Clayworker*, **28**, 266 (1920).—Bricks of burned clay whether solid or perforated, and hollow blocks must satisfy the following requirements: (1) They must have a uniform texture, free from laminations; (2) they must conform to within 2 per cent of the standard length and within 3 per cent in thickness; (3) they must not absorb more water than corresponds to 12 per cent of the weight of the brick; (4) they must not be affected by freezing; (5) they must not contain more than 1 per cent of soluble salts; (6) they must have a crushing strength of (*a*) 200 kilgs. per sq. cm. (2,800 lbs. per sq. in.) for solid first-class brick; (*b*) 80 kilgs. per sq. cm. (1,120 lbs. per sq. in.) for solid second-class bricks; (*c*) 50 kilgs. per sq. cm. (700 lbs. per sq. in.) for hollow blocks or perforated bricks; (*d*) 225 kilgs. per sq. cm. (3,150 lbs. per sq. in.) for pavers.

The tiles should measure 13 to the meter or 22 to the meter, respectively and must fulfil the following requirements: (1) Their texture must be uniform, free from fissures and laminations, and the tiles must ring well; (2) the color must be uniform in first-class tile; (3) the shape must be such that adjacent tiles lie properly on each other; (4) the tiles must not be affected by freezing (5) the tiles must not contain particles of free lime; (6) the tiles must resist a bending weight of 100 kilgs. (220 lbs.). H. G. SCHURECHT.

PATENTS

Plastic-block-cutting machine. H. R. STRAIGHT. U. S. 1,332,693, March 2, 1920. Plastic material extruded from a die is fed onto a downwardly curving off-bearing belt. The cutting wires are normal to the curvature of this belt. These wires are carried directly by a table which reciprocates transversely of the plastic ribbon and this table in turn is carried by one which moves longitudinally with the extruded material. G. E. MIDDLETON.

Abrasives

Aluminous abrasive, a new. OTIS HUTCHINS. *Chem. Met. Eng.*, **22**, 565 (1920).—A new abrasive material has been perfected by the Carborundum Company. Impurities are present in the new abrasives to about 1.5%, or very much less than in the ordinary type of aluminous abrasive. This has a

bearing on the characteristics of the abrasive grain and the wheel made from it. Its cutting power is increased due to the greater amount of crystallized alumina present. There is less fluxing between the bond and the grain, this resulting in a brittle wheel so necessary for rapid cutting. It also makes it possible, due to the high purity of the grain, to produce wheels of very soft grade. The small amount of impurities allowed to remain in the abrasive is beneficial. It prevents the formation of skeletal crystals and prevents the more or less open and porous structure which is obtained when molten pure alumina is allowed to solidify. The resulting abrasive consequently exhibits a greater toughness and the wheel has a longer life. As the grits commonly used are 20 and finer, almost every individual grit will consist of a fragment broken from a larger crystal of alumina and due to this fact will possess exceptional sharpness. When the alumina crystals in the abrasive are small, a rupture of the grain may mean a tearing away of a few small crystals without fracture. However, when the crystals are large and a rupture occurs in an abrasive grain, it means that a crystal of alumina has been actually fractured and that new sharp cutting points and edges have been produced.

A. J. LAMBERT.

Artificial abrasives, the manufacture of, in the electric furnace. C. J. BROCKBANK. *Jour. Soc. Chem. Ind.*, **39**, T, 41–44.—Artificial abrasives require for their production large quantities of electricity, and therefore, the industry has developed in Canada and the United States where such power can be furnished cheaply owing to the enormous water power developments there. Artificial abrasives are of two groups, the silicon carbide and the aluminous. The refractory by-products are also of great value. Natural abrasives were the only efficient ones in use until carborundum (silicon carbide) was discovered by Acheson in 1890. Silicon carbide cannot be used for all classes of grinding, and it was an attempt to make it a universal grinding material which nearly resulted in financial disaster to the Carborundum Company. Its physical properties render it unsuitable for producing the fine smooth finish required in steel grinding. The discovery of carborundum therefore was not entirely responsible for the diminished use of natural abrasives, but the natural deposits were being rapidly exhausted due to the constantly growing demands of industry, and another artificial abrasive made from the aluminous ores was discovered which completed the requirements of the abrasive field. A typical mix used in the commercial production of silicon carbide is 150 pounds petroleum coke, 2520 pounds white sand, 300 pounds sawdust, and 40 pounds salt. A considerable proportion of the mixture remains unconverted, acting merely as a heat-insulating blanket, and will ordinarily be returned to the mixing department to be added to the new materials. Petroleum coke is the form of carbon which has proved most satisfactory for the production of the highest grade silicon carbide, because of the readiness with which it can be converted into graphite by heat. Silicon carbide furnaces are built in sizes varying from 1000 h. p. to 3000 h. p. capacity. A furnace of the larger size will produce approximately 7% more silicon

carbide per unit power input, but this gain is somewhat offset by the fact that the quality of the product is not so good. The furnace transformers used are oil insulated, water-cooled, single phase, and by means of a tap taken off the high-tension side it is possible to obtain any voltage from 160 to 85. The highest voltage is used when the furnace is first cut in, and it should reach full load in less than 3 hours, after which the voltage must be periodically reduced or the furnace will run over-load due to the negative coefficient of the graphite resistor. The side walls must not be taken down for at least 24 hours after the furnace has been disconnected as the product is liable to be injured by oxidation. Subsidiary reactions involving to some degree recrystallization of the product take place after the furnace is disconnected. A typical mix used in the commercial production of the aluminous abrasives is 100 lbs. coke, 1750 lbs. bauxite, 350 lbs. iron borings, smelted in an arc furnace. These furnaces operate at about 100 volts and require 550 k. w. Reduction must not be carried too far, otherwise the abrasive will be too pure and brittle. The power is a small proportion of the total manufacturing cost, and it would, therefore, seem that aluminous abrasives might, quite practicably be manufactured in England, and important developments in this field are to be expected in the near future. J. VAN DE WATER.

Review of the abrasive materials situation in 1919. F. J. KATZ. *Eng. Min. Jour.*, **109**, 231–232 (1920).—This general review includes notes on the following materials: Emery and corundum, garnet, pumice and artificial abrasives. The conditions of these various industries are briefly mentioned. E. D. ELSTON.

Cement and Lime

PATENTS

Cement. T. A. SHINN. U. S. 1,334,272, March 16, 1920. A hydraulic cement comprising Portland cement and ground slag sand, thoroughly mixed.

Cements and similar products, process for the manufacture of. M. L. BOILLOT AND J. DAUDIGNAC, U. S. 1,332,422, March 2, 1920. The constituent parts of the cement are ground, mixed, fused to molten condition in an electric furnace, and the fused mass run into molds, cooled and ground. Owing to the high temperature obtained the materials completely react on each other to form calcic silicates and aluminates. Hydraulic products having any desired indexes of "hydraulicity," composition, color and quickness of set may be obtained by a proper selection of the raw materials. Examples of some of these raw materials are: Primary rocks such as gneiss and mica-schists; volcanic rocks such as granite, basalt, lava, etc.; silicates of lime and iron; natural silicates of alumina; natural aluminates and bauxite; limestones or any calcium compounds; and blast furnace slags.

Magnesium-oxychloride cement. J. B. SHAW and G. A. BOLE. U. S. 1,333,510, March 9, 1920. The high grade magnesium carbonate heretofore used as the source of the magnesium oxide used in magnesium oxychloride cements is comparatively expensive and has made these cements too costly to compete with Portland cement despite their superiority for many purposes. It has been believed that the calcium carbonate present in impure magnesites caused shrinkage of the cement during setting and consequent cracking. These inventors have discovered, however, that calcium carbonate has no such deleterious effect but that calcium oxide has. They, therefore, employ ordinary dolomite, calcining it with great care in a muffle between 500° C and 815° C. Within this range all the magnesium carbonate is reduced to the oxide but the calcium carbonate remains unchanged. To this calcined mass either a calcium or magnesium chloride solution or a mixture of the two is added.

Plastic mixture and process of making it. M. K. ARMSTRONG. U. S. 1,331,554, Feb. 24, 1920. An electrolyte such as sodium phosphate is added to a clay slip in sufficient amount to precipitate the greater part of the soluble constituents of the clay and at the same time deflocculate it. One-half to $^3/_4\%$ of some organic colloid such as starch or dextrin is then added. To this is then added powdered calcined gypsum, about 40% of the gypsum to 60% of the slip. The mixture is suitable for uses to which plaster is usually put, especially plaster board.

ACTIVITIES OF THE SOCIETY

Important Actions of Board of Trustees

April 26. It was voted to maintain a booth at the Sixth National Exposition of Chemical Industries, in New York next September. A local committee was appointed as follows: Henry Schmidt, *Chairman;* R. L. Clare, Otto Will, G. H. Brown, W. L. Howat, August Staudt, Leslie Brown, and Chas. F. Binns. The local committee will equip the booth and, in consultation with the manager of the Exposition, will select the time and place for a meeting. The Committee on Coöperation will arrange the program for the meeting and will see to the representation of the Society at the opening general program. The Secretary or the Assistant Secretary will attend all meetings and attend to the registration and the enrollment of new members. Badges will be furnished to all members who register at the booth.

May 5. Inasmuch as the English Ceramic Society has been obliged to cancel their proposed trip to America this summer, it has been voted to hold the regular Summer Meeting in Chicago and vicinity. A meeting of the Chicago members will be called and a local committee chosen forthwith. Detailed plans will be announced as soon as possible.

May 13. It was voted to appoint Dr. E. W. Washburn, with Dr. G. A. Rankin as alternate, as delegate to the Organizing Conference called by the United Engineering Societies, to occur in Washington, D. C., June 3 and 4. The purpose of the Conference is for the "coöperation of engineering and allied technical organizations to further the public welfare wherever technical knowledge and engineering training are involved and to consider matters of common concern to these professions."

MEETING OF THE CHICAGO SECTION

On Friday, May 21st, the Chicago Section of the American Ceramic Society held a business meeting and a short program at the City Club, Chicago, with twenty members in attendance.

The primary purpose of the meeting was to elect a chairman to take charge of the arrangements for the Summer Meeting of the Society. F. B. Ortman was appointed to act as chairman, and he will choose his own committee.

Following the business session, two papers on enamels were presented, as follows: "The Enameling of Cast Iron," L. H. Menne, and "The Preparation of Steel for Enameling," L. G. Whitford. A very enthusiastic and interesting discussion on enamels followed the reading of these papers.

F. L. STEINHOFF, *Secretary.*

NECROLOGY

Mr. George Sweet.—Mr. George Sweet, of Brunswick, Australia, who died on the first Sunday in April, at the age of 75 years, had lived in Victoria since 1867. He was devoted to science, especially geology, and was a member of the Royal Society, the Field Naturalists' Club of Victoria, and of the American Ceramic Society since 1906. For many years he was chairman of the Pottery Manufacturers' Association, and employers' representative on the pottery wages board, and was also a member of the council and chairman of the Pottery Advisory Board of the Brunswick Technical School. He was, from its inception, a representative of the Council of Churches for Victoria.

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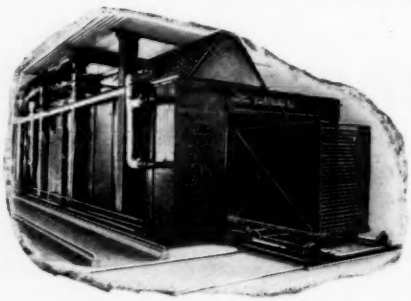

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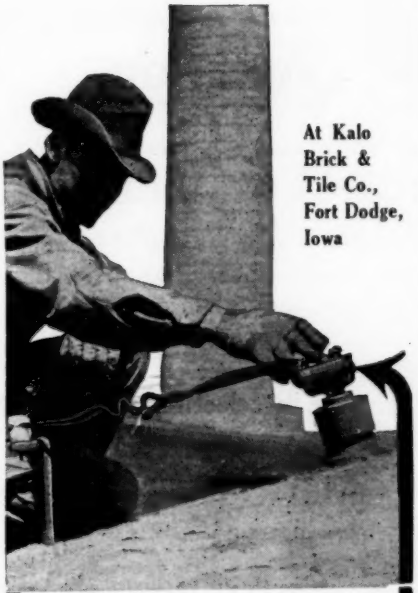

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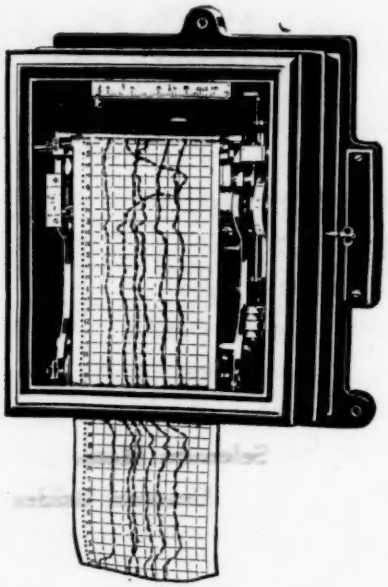

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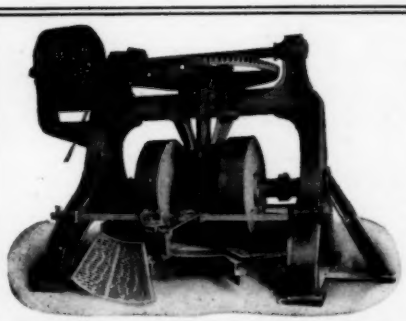

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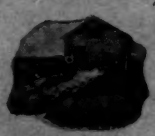

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